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ARMY PRELIMINARY EVALUATION. YAH-1S HELICOPTER WITH MODIFIED FL--ETC(U)
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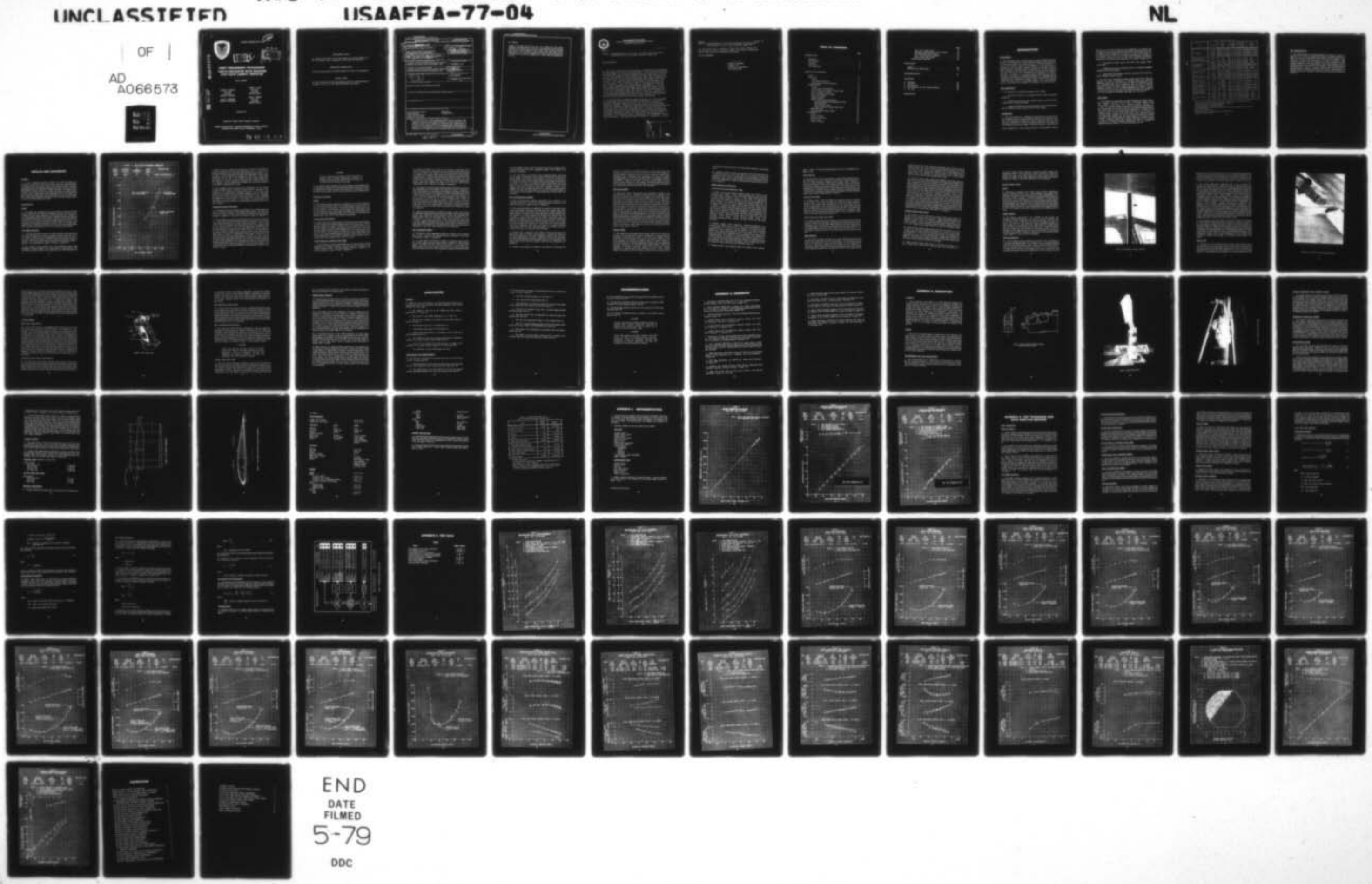

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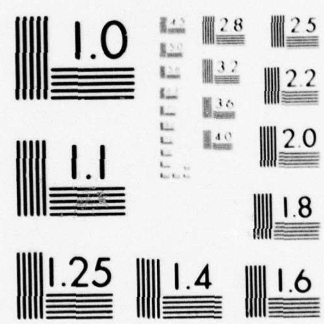

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USAAEFA PROJECT NO. 77-04

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ARMY PRELIMINARY EVALUATION YAH-1S HELICOPTER WITH MODIFIED FLAT PLATE CANOPY INSTALLED

FINAL REPORT

JAMES R. ARNOLD
MAJ, CM
US ARMY
PROJECT OFFICER

GARY L. SKINNER
PROJECT ENGINEER

JERRY R. GUIN
MAJ, FA
US ARMY
PROJECT PILOT

JOHN A. BISHOP
CW4, AV
US ARMY
PROJECT PILOT

AUGUST 1977

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UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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The United States Army Aviation Engineering Flight Activity conducted an Army Preliminary Evaluation of the YAH-1S helicopter to determine the effect of the modified flat plate canopy installation on performance and combined effects of the canopy and the Kaman K-747 rotor on handling qualities. The helicopter was tested from 18 March through 15 June 1977 at Edwards Air Force Base, California. During the test, 28 flights totaling 23.8 productive flight hours were flown. The over

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20. Abstract

increase in equivalent flat plate area due to the modified flat plate canopy installation was approximately 3 square feet. Two deficiencies noted during this evaluation were the high intensity of mirror images of both internal and external light sources on the modified flat plate canopy during night flight and the design/location of the night vision goggle switch, which is conducive to inadvertent deactivation of the visual fault warning system. A total of nine shortcomings were noted.

DEPARTMENT OF THE ARMY

HQ, US ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND
P O BOX 209, ST. LOUIS, MO 63166

DRDAV-EQ

21 DEC 1977

SUBJECT: USAAEFA PROJECT No. 77-04, Army Preliminary Evaluation YAH-1S with Modified Flat Plate Canopy Installed, August 1977

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1. The purpose of this letter is to present the Directorate for Development and Engineering position on the subject report. Except for the deficiencies and shortcomings, this Directorate agrees with the conclusions of paragraph 57. The mirror images of both internal and external light sources on the original and modified flat plate canopy during night flight (paragraph 58a) have long been of concern to this organization, particularly their impact on safety. User evaluation however, has deemed this disadvantage to not be serious and in fact acceptable in light of the reduced detectability due to sun glint, which is the reason for the incorporation of the flat plate canopy. Regarding the other deficiency (paragraph 59), a fix has been accomplished by installing Night Vision Goggle (NVG) enable switch on the pilot's instrument panel, which returns the instrument light level to the full bright position when the power is turned off. The gunner's caution panel is similarly protected. Action is not being taken on any of the shortcomings (paragraph 59) since they are inherent to the basic AH-1 and are not the result of the flat plate canopy installation.

2. The AH-1S Production Operators Manual delineates the correct procedure for an inflight fire in the AH-1S production helicopter. It should be noted that the manual does not state to turn off the generator as an emergency procedure. However, the operators manual for the AH-1S (Mod) Helicopter, reference 5, appendix A states that both the battery and generator should be turned off during an in-flight fire. In view of the above, it is possible for a pilot who is familiar with the procedures of flying the AH-1S (Mod) Helicopter to apply this same procedure to the AH-1S Production Helicopter, which would result in the loss of the instruments stated in paragraph 51 of the subject report. Consequently, the recommended "Caution" note is desirable. The Operators Manual, reference 4, appendix A is correct

DRDAV-EQ 21 DEC 1978

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that the caution note is required to insure that pilots familiar with the emergency procedures of the AH-1S (Mod) do not become confused and utilize them on the AH-1S production helicopter.

FOR THE COMMANDER:

WALTER A. RATCLIFF
Colonel, GS
Director of Development
and Engineering

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INTRODUCTION

BACKGROUND

1. The United States Army Aviation Systems Command (AVSCOM)* previously tasked the United States Army Aviation Engineering Flight Activity (USAAEFA) to evaluate the installation of a flat plate canopy on an AH-1Q helicopter (ref 1, app A). This evaluation resulted in the modification of the canopy design to incorporate convex side panels. AVSCOM awarded a development contract to Kaman Aerospace Corporation (KAC) to design, fabricate, and test an improved main rotor blade for the AH-1 series helicopter. This blade has been designated the K-747. In February 1977, AVSCOM directed USAAEFA to conduct a performance evaluation of a production prototype AH-1S helicopter with the redesigned canopy installed and standard Bell Helicopter Textron (BHT) B-540 main rotor blades, and to determine the combined effects of the K-747 rotor and the modified flat plate canopy on the handling qualities of the YAH-1S helicopter (ref 2). A test plan for the evaluation was published in June 1977 (ref 3).

TEST OBJECTIVES

2. The objectives of this flight test program were as follows:

a. Determine the effects of the modified flat plate canopy on helicopter performance.

b. Determine the adequacy of the modified flat plate canopy with respect to internal and external night lighting.

c. Evaluate the stability and control characteristics of the YAH-1S helicopter with the modified flat plate canopy and K-747 rotor installed.

DESCRIPTION

3. The AH-1S helicopter is a 10,000-pound attack helicopter derived from the AH-1G helicopter that was modified with the improved Cobra armament system. The AH-1S incorporates uprated drive system components from the AH-1J SeaCobra, a BHT Model 212 tail rotor, and the Lycoming T53-L-703 engine, with an uninstalled thermal power rating of 1800 shaft horsepower (shp), limited to

*Since redesignated the Army Aviation Research and Development Command.

1290 shp for 30 minutes by the main rotor transmission. Four wing-mounted external stores locations are provided, two on each side of the fuselage. The aircraft is configured with an integral chin turret that can be aimed by the gunner. The test helicopter (SN 70-16019) was a production prototype AH-1S, described in the operator's manual (ref 4, app A). This aircraft incorporates the following changes from the modified AH-1S, described in the operator's manual (ref 5).

a. Seven-plane flat plate canopy with convex side windows bulged 1-1/8 inches.

b. Redesigned front and rear instrument panels, to incorporate redesigned instruments with integral lighting.

c. Replacement of the emergency collective accumulator with an electrically driven emergency hydraulic system.

4. The K-747 rotor incorporates an advanced design airfoil with a tapered tip planform. The blades are constructed of composite material with a multicell, ballistically tolerant spar. The K-747 rotor can replace the standard AH-1 main rotor, designated B-540, without modification other than pitch link assembly adjustment. Appendix B provides detailed descriptions and photos of the test helicopter and the K-747 rotor. A detailed description of the AH-1G is contained in the operator's manual (ref 6, app A). A detailed description of the Model 212 tail rotor is contained in USAASTA Final Report No. 72-30 (ref 7).

TEST SCOPE

5. The evaluation was conducted on the YAH-1S helicopter at Edwards Air Force Base, California (2302-foot field elevation). Twenty-eight flights totaling 23.8 productive flight hours were conducted between 18 March and 15 June 1977. USAAEFA installed, calibrated, and maintained all instrumentation, and was responsible for test aircraft maintenance and logistical support during the tests. Flight restrictions and operations were established by the modified AH-1S operator's manual and the safety-of-flight release (ref 8, app A) issued by AVSCOM. Primary emphasis was directed toward aircraft performance. Aircraft test configurations included clean (no wing stores) and 8-TOW (two dual-TOW launchers on each outboard wing store location). Flight test conditions are shown in table 1. Handling qualities were evaluated with respect to the applicable requirements of military specification MIL-H-8501A (ref 9), as amended by approved deviations defined in the detail specification (ref 10).

Table 1. Flight Test Conditions.[1]

Test	Configuration	Gross Weight (lb)	Calibrated Airspeed (kt)	Center-of-Gravity Location (in.)	Density Altitude (ft)
Level flight Performance[2]	Clean[3]	8320 and 9140	44 to 152[5]	192.6 (fwd)	6400 and 9280
	8-TOW[4]	8780 to 9720	47 to 138[5]	192.5 (fwd)	4680 to 10,900
	8-TOW	8380 and 9360	44 to 142[5]	199.5 (aft)	6220 and 8600
Autorotational descent performance[2]	8-TOW	9760	34 to 117	192.5 (fwd)	5000
Control positions in trimmed forward flight[2]	Clean	9140	42 to 122	192.6 (fwd)	9280
	8-TOW	9180 to 9360	43 to 116	192.6 (fwd)	5000 to 9240
	8-TOW	9360	43 to 119	199.5 (aft)	8600
Static longitudinal stability	8-TOW	9240 and 9580	64 and 105	199.8 (aft)	4960 and 4820
Static lateral-directional stability	Clean	7800 and 8040	61 and 102	199.6 (aft)	5200 and 4980
	8-TOW	9120 and 9440	64 and 105	199.6 (aft)	5200 and 4980
Maneuvering and dynamic stability[6]	8-TOW	9520 to 10,040	64 and 105	196.0 (mid)	6600 to 7160
Mission maneuvering characteristics	8-TOW	9200 to 10,200	Zero to V_{NE}[7]	192.2 (fwd)	4000 to 5000
Night operations	8-TOW	9500	Zero to V_{NE}	192.0 (fwd)	3500 to 5000
Simulated sudden engine failure	8-TOW	9300	64 and 105	191.8 (fwd)	7000
Airspeed calibration	Clean	8320	32 to 141	199.8 (aft)	5220
	8-TOW[2]	9340	40 to 115	192.7 (fwd)	5020

[1]Test conditions unless otherwise noted: Rotor speed 324 rpm; environmental control system OFF; SCAS ON; K-747 main rotor blades installed.
[2]Standard B-540 main rotor blades installed.
[3]Clean configuration: Clean wing stations.
[4]8-TOW configuration: Four TOW missiles mounted on each outboard wing station; inboard wing stations clean.
[5]Knots true airspeed (KTAS).
[6]Dynamic stability tests conducted with SCAS ON and OFF.
[7]V_{NE}: Never-exceed airspeed.

TEST METHODOLOGY

6. The engineering flight test techniques described in references 11 through 13, appendix A, were used in conducting performance and handling qualities tests. Flight test data were hand-recorded from calibrated test and standard cockpit instruments. A listing of test instrumentation is contained in appendix C. Pilot comments were used to aid in the analysis of data and to determine the overall qualitative assessment of the flying qualities of the YAH-1S helicopter with the modified flat plate canopy and K-747 rotor installed. A Handling Qualities Rating Scale (HQRS) (fig. 1, app D) was used to augment pilot comments relative to handling qualities. Performance limitations were based on power-available data presented in reference 4, appendix A. Data reduction techniques are described in appendix D.

RESULTS AND DISCUSSION

GENERAL

7. An Army Preliminary Evaluation (APE) of the YAH-1S helicopter was performed to determine the effect of the modified flat plate canopy installation on performance and the combined effects of the canopy and K-747 rotor blade on handling qualities. Miscellaneous engineering tests included vibration evaluation, blade/fuselage structural interference, cockpit evaluation, and airspeed system calibration. Two deficiencies were noted during this evaluation: the high intensity of mirror images of both internal and external light sources on the modified flat plate canopy during night flight, and the design/location of the night vision goggle (NVG) switch allows inadvertent deactivation of the visual fault warning system. A total of nine shortcomings were noted.

PERFORMANCE

General

8. Level flight and autorotational descent performance testing was conducted on the YAH-1S with the B-540 rotor installed to determine the effects of the modified flat plate canopy installation. All performance tests were conducted at zero sideslip flight conditions. The increase in equivalent flat plate area (Δf_e) due to the canopy installation was approximately 3 square feet (ft^2) at airspeeds above 90 KTAS. The Δf_e between the clean and 8-TOW configurations was 5 ft^2. The longitudinal center-of-gravity (cg) location had little effect on level flight power required. During autorotational descents, the rate of descent increased abruptly when airspeed was descreased below 40 knots indicated airspeed (KIAS).

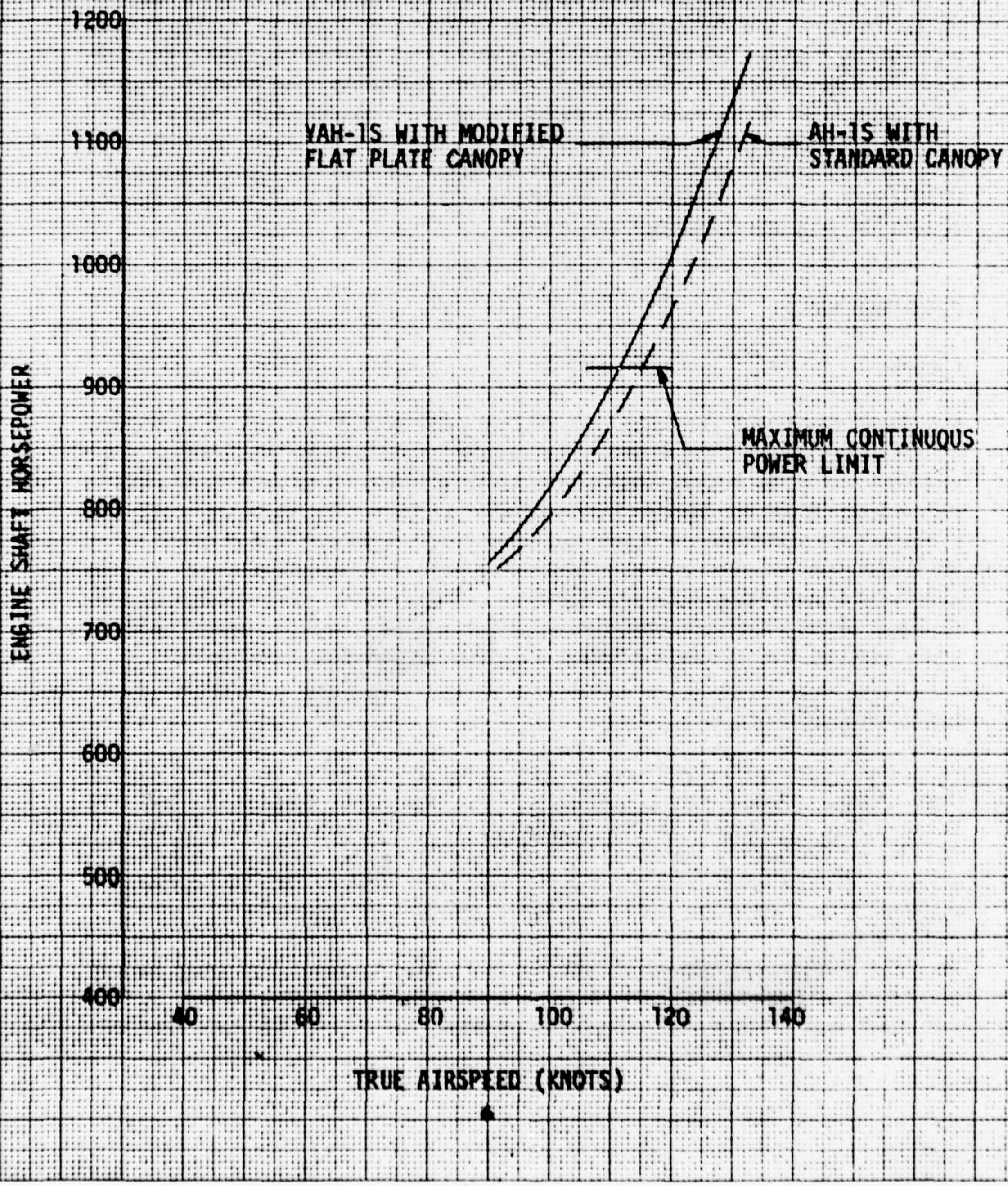
Level Flight Performance

9. Level flight performance tests of the YAH-1S helicopter with modified flat plate canopy installed were conducted to determine power required and fuel flow as a function of airspeed for the configurations and conditions listed in table 1. Data were obtained in stabilized level flight utilizing the technique described in appendix D. The results of these tests are presented nondimensionally in figures 1 through 3, and dimensionally in figures 4 through 13, appendix E.

10. The increase in power required due to the modified flat plate canopy installation is depicted in figure A for a gross weight of 10,000 pounds at 95°F and 4000 feet pressure altitude. Power required for the AH-1S helicopter with

FIGURE A. LEVEL FLIGHT PERFORMANCE COMPARISON

GROSS WEIGHT (LB)	PRESSURE ALTITUDE (FT)	AIR TEMPERATURE (°C)	ROTOR SPEED (RPM)	CONFIGURATION
10000	4000	35	324	CLEAN/B-540 ROTOR/FWD CG



a standard canopy was obtained by extracting power required in level flight for the clean configuration from the AH-1G performance report (ref 13, app A) and adding the drag effects of a TOW missile sight installation (approximately 2.6 ft^2 per BHT). A clean configuration was utilized for comparison to better enable determination of the effect of the modified flat plate canopy on level flight performance. The Δf_e due to the modified flat plate canopy installation is approximately 3 ft^2 when calculated at airspeeds above 90 KTAS. This relates to a reduction in maximum airspeed for level flight (V_H) at maximum continuous power (MCP) of approximately 4 knots.

11. The comparison between external stores configurations for the YAH-1S modified flat plate canopy is presented in figures 10 and 11, appendix E. The comparison of cg configurations is presented in figures 12 and 13. Test results indicate that the effective Δf_e of an 8-TOW configuration was 5 ft^2. This differs from the 6.5 ft^2 stated in the AH-1S operator's manual (ref 4, app A). Changing the longitudinal cg location appears to have little effect on power required for level flight. Test data show that for a 7-inch change in cg, Δf_e was only 1 ft^2. This represents a marked reduction in Δf_e with Δcg when compared to the AH-1G (ref 14, app A).

Autorotational Descent Performance

12. Autorotational descent performance was evaluated in the 8-TOW configuration with the B-540 rotor system at the conditions listed in table 1. The tests were flown at an average rotor speed of 324 rpm and zero sideslip, using the technique described in appendix D. Test results are presented in figure 14, appendix E.

13. The minimum rate of descent of 1950 feet per minute (ft/min) was achieved at 61 knots calibrated airspeed (KCAS) (airspeed for minimum rate of descent ($V_{min\ R/D}$)) and increased by less than 5 percent throughout an airspeed range of 47 to 78 KCAS. Airspeed for maximum glide distance ($V_{max\ glide}$) occurred at 93 KCAS and resulted in a rate of descent approximately 350 ft/min greater than the minimum $V_{min\ R/D}$ and $V_{max\ glide}$ differed from those presented in the AH-1S operator's manual (ref 4, app A). However, since this difference represents less than a 1-percent change in minimum rate of descent and maximum glide distance no revision is recommended to the operator's manual (ref 4). As airspeed was decreased below approximately 43 KCAS, the rate of descent increased abruptly, approaching 3900 ft/min at 36 KCAS. At these lower airspeeds, the descent path approached the vertical with level pitch attitudes, and precise airspeed control was difficult. Due to the high rates of descent at airspeeds below 43 KCAS (40 KIAS), and the inaccuracy of the ship's airspeed system at low airspeed (para 56), the following CAUTION is recommended for inclusion in the operator's manual:

CAUTION

The ship's airspeed system provides unreliable information at airspeeds below 40 KIAS. Steady-state autorotation at indicated airspeeds below 40 KIAS will result in excessive rates of descent and near-vertical descent angles.

14. No unusual airframe vibrations were noted during any autorotational entries or in steady-state descents within the airspeed range evaluated. Rotor speed response to collective pitch changes was rapid, causing difficulty in maintaining a precise 324 rpm, but rotor speed could be easily maintained within operational limits.

HANDLING QUALITIES

General

15. The handling qualities evaluation was conducted on the YAH-1S helicopter to determine the combined effects of the modified flat plate canopy and the K-747 rotor on helicopter flying qualities. One handling qualities deficiency noted was the high intensity of mirror images of both internal and external light sources on the modified flat plate canopy during night flight. Three shortcomings noted were the weak static longitudinal stability at cruise airspeeds, the weak directional stability about trim, and the weak side-force characteristics.

Control System Characteristics

16. Flight control system characteristics were evaluated on the ground with engine and rotor stopped and externally supplied electric and hydraulic power, using the technique described in appendix D. Control forces were measured with force trim ON and stability and control augmentation system (SCAS) OFF. Cyclic and directional control system free play was negligible and control centering was positive but not absolute. Control dynamics in both systems were highly damped, with only one or two small overshoots apparent, and were verified in flight. The control system characteristics of the YAH-1S are satisfactory and comparable to those of previous AH-1 series helicopters (refs 1 and 15, app A).

Control Positions in Trimmed Forward Flight

17. Control positions in trimmed forward flight were determined during level flight performance and airspeed calibration tests. The tests were conducted at the conditions listed in table 1, using the technique described in appendix D. The data are presented in figures 15 and 16, appendix E.

18. During level flight (fig. 15, app E), the variation of longitudinal control position with airspeed was essentially linear, with increased forward cyclic required for increased airspeed. The variation of lateral and directional control positions with airspeed was nonlinear. Both controls moved right with increasing airspeed to approximately 75 KCAS and then moved left as airspeed increased to V_H. These reversals were not discernible to the pilot. The total control variations were 1 inch and 0.6 inch for the lateral and directional controls, respectively, throughout the airspeed range tested. Within the scope of this test, the control position characteristics of the YAH-1S in level flight are satisfactory.

19. The variation of control position during level flight with changes in cg location and configuration (clean and 8-TOW) is also presented in figure 15, appendix E. There were essentially no control shifts due to changes in configuration. The change in cg location from forward to aft resulted in a further forward longitudinal control position and the lateral and directional controls were essentially unaffected. In an aft cg 8-TOW configuration, the forward longitudinal control margin was approximately 15 percent at V_H. For a cg shift of approximately 7 inches, the maximum longitudinal control shift was less than 2 inches (21 percent of control throw). Since jettison of the 8-TOW missiles would result in changes in cg location of less than 1 inch, such a jettison would not cause large trim changes. The control position trim changes in the YAH-1S due to cg location and configuration changes are satisfactory.

20. During autorotational descent and MCP climb (fig. 16, app E), the variation of longitudinal control position with airspeed was slightly nonlinear, with increased forward cyclic required for increased airspeed or power. The longitudinal trim change between climb and autorotation varied from approximately 1 inch at 53 KCAS to 1.7 inches at 113 KCAS. Lateral control position moved right 1.3 inches as airspeed increased from 41 to 113 KCAS during autorotation, but varied only slightly during climb. Directional control position remained constant during climb and autorotation and trim shifts between climb and autorotation are comparable to other AH-1 series helicopters and are satisfactory.

Static Longitudinal Stability

21. Collective-fixed static longitudinal stability was evaluated at the conditions listed in table 1, using the test technique described in appendix D. Test results are presented in figure 17, appendix E.

22. At a trim airspeed of 64 KCAS, the variation of longitudinal control position with forward airspeed indicated positive stability, although the control position gradient was shallow (0.6 inch of forward cyclic from 43 to 85 KCAS). This shallow gradient made precise airspeed control difficult, but normal mission tasks within this airspeed range were easily accomplished. During nap-of-the-earth (NOE)

or contour flights, airspeed could be varied with small control changes, thereby reducing pilot fatigue. The static longitudinal stability of the YAH-1S at low airspeeds is satisfactory.

23. At a trim airspeed of 105 KCAS, static longitudinal stability, as indicated by the variation of longitudinal control position with airspeed, exhibited weak positive stability. The forward cyclic movement was only 0.3 inch from 85 to 125 KCAS. This shallow control position gradient made airspeed control difficult and resulted in a tendency to overshoot a desired airspeed. Mission and training tasks such as cross-country flight, formation flight, or flight escort require good airspeed control, and therefore the weak static longitudinal stability at cruise airspeeds will result in considerable pilot effort to maintain the desired airspeed (HQRS 5) and will hasten pilot fatigue. The weak static longitudinal stability of the YAH-1S at cruise airspeeds is a shortcoming noted on other AH-1 series helicopters.

Static Lateral-Directional Stability

24. Static lateral-directional stability characteristics were evaluated at the conditions listed in table 1, using the test technique described in appendix D. Test results are presented in figures 18 and 19, appendix E.

25. Static directional stability, as indicated by the variation of directional control position with sideslip, was positive (left pedal required to maintain right sideslip) at the airspeeds tested. Directional control variation with sideslip was shallow for sideslip angles of ±4 degrees but increased significantly at greater sideslip angles. This variation also increased slightly with increased trim airspeed. There was essentially no change between the clean and 8-TOW configurations. Directional stability was qualitatively noted as being reduced from the AH-1G. Ball-centered flight and zero sideslip flight were difficult to maintain and there was a tendency for small, undamped yaw oscillation (±3 degrees from trim). During simulated attack dives, considerable pilot effort was required to maintain coordinated (ball-centered) flight. The weak directional stability of the YAH-1S near trim is a shortcoming noted on other AH-1 series helicopters.

26. Dihedral effect, as indicated by the variation of lateral control position with sideslip, was positive (left lateral control required to maintain left sideslip) for the 8-TOW configuration. In the clean configuration, dihedral effect was positive with right sideslip angles and decreased to neutral with increasing left sideslip angles. The neutral dihedral effect with left sideslip angles was not objectionable. The dihedral effect of the YAH-1S is similar to prior AH-1 series helicopters and is satisfactory.

27. Side-force characteristics, as indicated by the variation of bank angle with

sideslip, were positive (left roll attitude required to maintain left sideslip). The roll attitude gradient increased with increased airspeed. The 8-TOW configuration exhibited slightly stronger side force than the clean configuration. During mission maneuvering tasks, considerable pilot compensation was required to maintain coordinated flight due to the weak directional stability and inadequate side-force cues (HQRS 5). Because of the nature of contour and NOE flight, the pilot's attention must be directed out of the cockpit. Uncoordinated flight was common during these types of maneuvers. The weak side-force characteristics of the YAH-1S are a shortcoming noted on other AH-1 series helicopters.

Maneuvering Stability

28. Maneuvering stability characteristics were quantitatively evaluated at the conditions listed in table 1, utilizing the technique described in appendix D. The tests were conducted with the K-747 rotor installed and at high engine power settings (94 percent torque at 64 KCAS and 88 percent torque at 105 KCAS). Test results are presented in figures 20 and 21, appendix E. The variation of longitudinal control position with normal load factor was positive (aft control movement with increasing load factor) and essentially unchanged from the AH-1G. The discontinuity in the variation of longitudinal control position with normal load factor was probably caused by the effective loss of SCAS input due to full actuator extension (ref 16, app A). At 64 KCAS (left and right turns), the aircraft was easy to control and precise airspeed control was accomplished with minimal pilot effort. At 105 KCAS, and above approximately 1.35 normal load factor, precise airspeed control became very difficult due to a longitudinal oscillation. Although the pilot had difficulty in maintaining precise trim airspeeds, no divergent tendencies were noted. This longitudinal oscillation was probably caused by the effective loss of SCAS input, as mentioned above. The decrease in maneuvering stability at higher airspeeds and above 1.35 normal load factor increased pilot workload in maintaining precise trim airspeeds at high angles of bank, but this characteristic will not adversely affect mission maneuvers.

Dynamic Stability

29. The longitudinal and lateral-directional dynamic stability of the YAH-1S was evaluated at the conditions listed in table 1, utilizing the test techniques described in appendix D. The short-term response of the YAH-1S was essentially the same as the AH-1G. With SCAS engaged, the response was essentially deadbeat and with SCAS disengaged, the response was lightly damped. The primary response to external gust inputs was a mild lateral-directional oscillation that was well-damped and easily controlled by the pilot with SCAS engaged (HQRS 3). With SCAS disengaged, the oscillation was lightly damped and increased pilot workload significantly at airspeeds greater than 100 KIAS. However, aircraft handling qualities at airspeeds below the 100 KIAS recommended in the operator's manual

for SCAS OFF operations provide a safe return-to-base capability in this degraded mode.

30. Long-period dynamic response was evaluated at 105 KCAS with SCAS ON by slowing the aircraft 10 to 15 knots below the trim airspeed and then slowly returning the cyclic control to the trim position. Aircraft response was oscillatory and damped, with a period of approximately 70 seconds. The long period of the YAH-1S was qualitatively evaluated as being slightly less damped than the AH-1G but is satisfactory.

Mission Maneuvering Characteristics

Accelerations/Decelerations/High-Speed Flight:

31. Lateral acceleration/deceleration handling qualities were evaluated at the conditions shown in table 1. Lateral accelerations/decelerations were conducted at an approximate skid height of 50 feet at a gross weight of 9900 pounds. The test gross weight divided by density air ratio (W/σ) was approximately 11,000 pounds. The aircraft was stabilized at the desired hover height and then lateral acceleration was initiated by simultaneously applying lateral cyclic and increasing collective pitch to achieve maximum power. Lateral control was used to maintain a constant skid height as the aircraft accelerated. Lateral control reversals were initiated at maximum sideward velocity by reducing collective pitch and executing a side-flare maneuver while attempting to maintain altitude. During right lateral accelerations, maximum left directional control displacement was achieved as sideward velocity approached 10 KTAS. Hovering under these test conditions required a high power setting, which could explain the lack of left directional control margin. Aircraft handling qualities during lateral accelerations/decelerations were essentially the same as with other AH-1 series helicopters.

32. Handling qualities during longitudinal accelerations/decelerations were evaluated at the conditions shown in table 1. The aircraft was stabilized in a hover at a skid height of 40 to 50 feet, power was increased to maximum, and forward longitudinal cyclic was applied to increase airspeed to V_H while maintaining altitude. After airspeed was stabilized at V_H at a skid height of 40 to 50 feet, power was reduced and aft longitudinal cyclic was applied to reduce airspeed while maintaining altitude. The tendency to enter power settling at the termination of a rapid deceleration was previously reported on the YAH-1R helicopter (ref 15, app A) and was noted during these tests. Power settling was avoided by decreasing the deceleration rate as the aircraft approached a hover. Forward field of view was obstructed during accelerations and decelerations (para 47).

33. Handling qualities during high-speed flight were evaluated at the conditions

shown in table 1. No adverse handling qualities were noted in high-speed level flight or dives.

Pop-Ups/Bob-Ups:

34. Pop-up/bob-up maneuvers were evaluated at the conditions listed in table 1. The bob-up maneuver was accomplished by establishing an in-ground-effect (IGE) hover and then conducting a maximum power vertical climb to establish an out-of-ground-effect (OGE) hover. This maneuver simulated a climb above a masking obstacle and engaging a target from an OGE hover. The pop-up maneuver was accomplished by establishing 40-KIAS NOE flight and then using aft cyclic and collective pull to maximum power to establish a climbing, decelerating flight path to an OGE hover, simulating unmasking and target engagement. No adverse handling qualities were observed during pop-ups or bob-ups.

Nap-of-the-Earth Flight:

35. Handling qualities during NOE flight were evaluated under the conditions shown in table 1. The aircraft was flown over rolling desert terrain with sparse vegetation from airspeeds below transitional lift to V_H at skid heights of 50 feet or less. Forward field of view was obstructed by the canopy vertical supports (para 47). Reflections from the ground and instrument panel on the canopy side panels also hindered outside vision. Sideslip changes of 10 to 15 degrees in either direction were common during low-speed maneuvers, which contributed to large errors in the ship's airspeed system (para 56).

Target Tracking and Rapid Target Shifts:

36. Handling qualities during target tracking and rapid target shifts were evaluated under the conditions shown in table 1. Moving targets were tracked with the aircraft in high-speed dives and during NOE flight. Rapid target shifts were also made in these flight regimes. Weak side-force characteristics gave the pilot inadequate cues of changing sideslip during both target tracking and target shifts (para 27). No other adverse handling qualities were noted during target tracking and rapid target shifts.

Night Operations

37. The YAH-1S helicopter was flown for a 2-hour night flight to evaluate the internal and external light reflectivity characteristics of the modified flat plate canopy. The helicopter was flown at varying altitudes over both sparsely lighted and mid to high density lighted (city and airport) areas. The reflections of full-intensity internal cockpit and instrument panel lighting produced mirror images in the canopy side panels of both crew stations, as well as in the forward overhead

canopy panel section. These reflections were greatly reduced when the internal lighting intensity was reduced to the mid range rheostat settings, but were still noticeable. The major area of pilot distraction due to internal lighting was the mirror image of the copilot/gunner instrument panel in the forward overhead canopy section. This reflection was most noticeable in areas of sparse ground lighting and obscured the pilot's forward field of view.

38. In areas of mid to high intensity ground lighting, external light reflections were noted in all canopy sections and these mirror images affected visibility from both crew positions. The greatest reflectivity occurred in turning maneuvers over densely lighted areas and the most pronounced mirror images were noted in the canopy side panels away from the direction of turn. Detecting other aircraft position lights through these side panel reflections was difficult. Additionally, the movement of the reflected ground lights across the top and side panels during low level maneuvering made it very difficult to establish and maintain a proper outside reference because reflected light images would tend to blend with the actual ground lighting. The reflectivity was affected by the intensity of the moon and was most severe during dark night conditions. The night mission pilot will have difficulty in maintaining a valid outside visual reference when maneuvering the helicopter over areas of mid to high density ground lights such as towns or flare-lit battle areas. Also, the apparent movement of mirror images across the canopy top and side panels will make the pilot highly susceptible to confusion and/or vertigo. The high intensity of mirror images of both internal and external light sources on the modified flat plate canopy during night flight is a deficiency.

Simulated Sudden Engine Failures

39. The response of the test helicopter to simulated sudden engine failures was evaluated at the conditions shown in table 1, using the technique described in appendix D. Engine failure was simulated by rapidly rolling the throttle to the flight-idle position. Controls were held fixed following the simulated power loss until the collective control was lowered to prevent exceeding a transient rotor speed of 275 rpm. Engine power settings varied from power for level flight to MCP.

40. During simulated sudden engine failures at 64 KCAS, the primary cue to loss of power was a left yaw acceleration accompanied by a change in yaw attitude of approximately 20 degrees. The aircraft entered a mild left roll. Collective delay time varied from 1 to 2 seconds, decreasing with increasing power settings. The maneuvers were mild and the aircraft was easily controlled during the recovery (HQRS 2). Rotor speed decay stopped immediately on lowering the collective and rotor speed control during the recovery was excellent.

41. During simulated sudden engine failures at 105 KCAS, the primary cue to loss of power was a rapid left roll. Collective delay time varied from 1 to

1.5 seconds. Aircraft control during the maneuvers required minimal pilot compensation (HQRS 3). Rotor speed decay stopped immediately on lowering the collective and rotor speed control during the recovery required little pilot compensation (HQRS 2). The sudden engine failure characteristics of the YAH-1S helicopter are similar to other AH-1 helicopters and are satisfactory.

MISCELLANEOUS TESTS

General

42. Miscellaneous engineering tests included canopy vibration, blade/fuselage structural interference, field of view, cockpit evaluation, and airspeed system calibration. One deficiency noted during these tests was the design/location of the NVG switch, which is conducive to inadvertent deactivation of the visual fault warning system. The shortcomings noted were obstruction to the pilot's forward field of view; location of the weapons control circuit breakers; lack of adequate separation between the wing stores jettison switch guard and the power turbine rpm INCR/DECR switch; inability to close the gunner canopy due to expansion during hot weather; and lack of a reliable airspeed system. An interference between the K-747 rotor blades and the pylon fairing under static conditions was also noted.

Canopy Vibration

43. The vibration characteristics of the modified flat plate canopy were qualitatively evaluated throughout the test. Dives to V_{NE} were conducted in both the clean and 8-TOW configurations and with both the B-540 and K-747 rotor systems. The vibration of the canopy side panels was negligible throughout the flight envelope. The top panels did exhibit a slight vibration at airspeeds greater than 100 KIAS, but this vibration was detectable only by placing the fingertips against the panels. No pilot distractions or obscuration of field of view were attributable to this slight vibration. The vibration characteristics of the modified flat plate canopy represent a significant improvement over the previous flat plate canopy design (ref 1, app A) and are satisfactory.

Structural Interference

44. A static fuselage clearance evaluation of the K-747 rotor was conducted at a maximum blade flapping angle of 12.25 degrees with no bending loads applied to the main rotor blades. Minimum canopy clearance occurred with full-up collective pitch and full-right cyclic and resulted in a clearance of 7.25 inches (photo A). A fuselage static interference was encountered at the top aft section of the upper pylon fairing (doghouse) with various combinations of cyclic and collective control

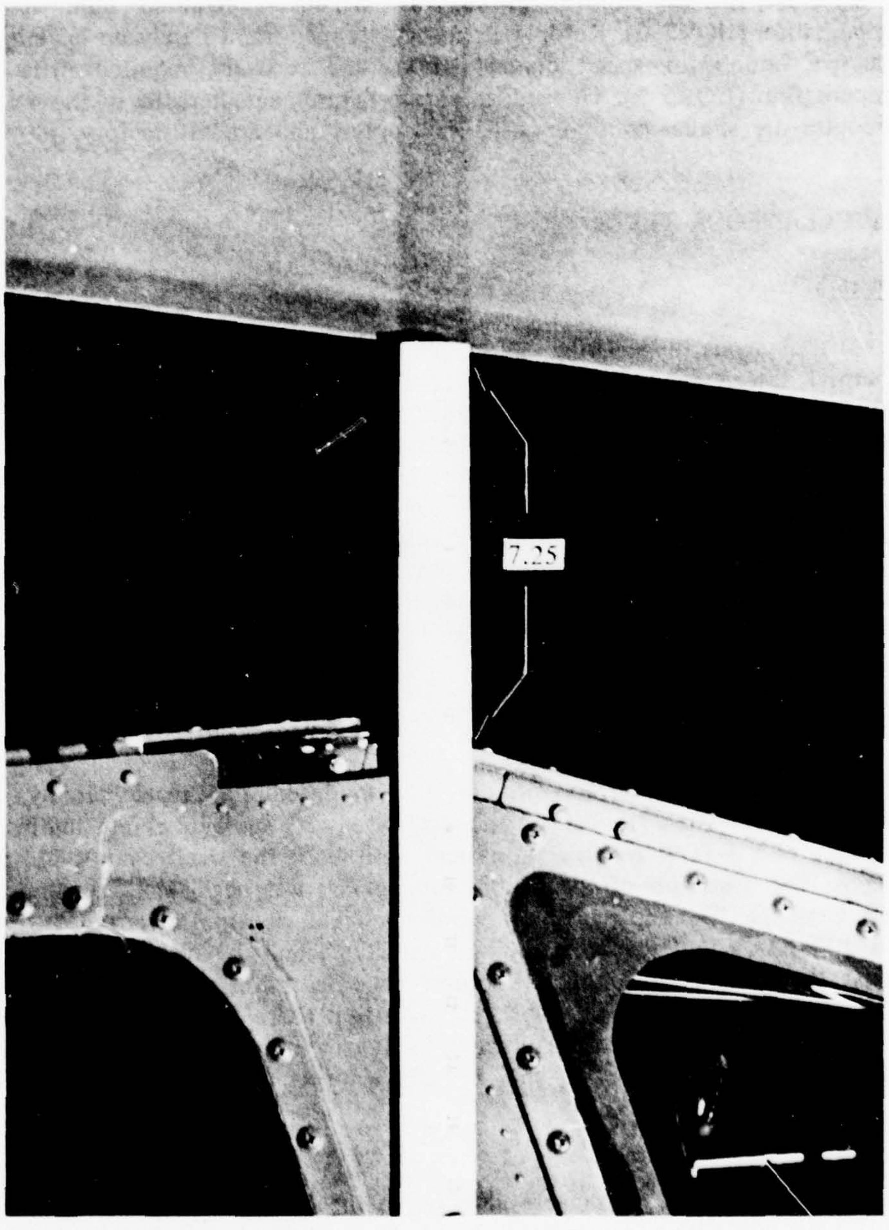


Photo A. K-747 Rotor to Canopy Clearance

positions (photo B). The initial points of contact on the blades were the inboard 9 inches of the trailing edge and the lock nut of the drag link retaining bolt. The maximum interference occurred with 100 percent up-collective in combination with left aft cyclic. The interference created an area of contact that extended 20 inches forward of the trailing tip of the pylon fairing and to a depth of 2.25 inches.

45. The control displacement combinations that result in initial K-747 rotor-to-pylon fairing contact are presented in figure 22, appendix E. This static evaluation was conducted at 100 percent of rotor flapping (forward blade up) and with no bending loads applied to the rotor blades. Although the combinations of control positions depicted would not be encountered during the conduct of normal aircraft maneuvers, there was some question as to the possibility of K-747 rotor-to-pylon fairing contact during minimum ground run autorotation touchdowns. With a typical mission loading at near-maximum gross weight and a forward longitudinal cg, large control applications of up-collective and aft cyclic would be required to minimize the autorotational ground run. Additionally, the presence of left crosswinds or sloping terrain may also require left cyclic displacement. These control displacement combinations correspond to those depicted in figure 22 that indicate the possibility of rotor-to-pylon fairing contact. The dynamic aspects of main rotor blade flapping and coning angles during low rotor speed autorotational touchdowns were not accounted for during this static evaluation. Additionally, the dynamic flapping effects and blade damage that might occur as a result of the rotor-to-pylon fairing contact are unknown. For these reasons, further testing was requested of the contractor to document the dynamic flapping and effects of main rotor blade-to-pylon contact.

46. KAC conducted whirl stand testing to evaluate the effects of the dynamic K-747 rotor-to-pylon fairing interference at normal rotor speeds (ref 16, app A). The pylon fairing was damaged by the blade contact but no damage occurred to the main rotor blades and no significant blade flapping was induced. In addition, KAC conducted a series of autorotations to a rough unprepared surface to investigate the possibility of blade/fuselage interference at high flapping angles (ref 17). Mast contact with the static stops was encountered (100 percent flapping) and no rotor-to-pylon fairing contact occurred. Although static rotor-to-pylon fairing interference is possible, the probability of an in-flight occurrence appears to be remote.

Field of View

47. The field of view of the YAH-1S helicopter with the modified flat plate canopy was qualitatively evaluated throughout the test program, with major emphasis on the mission maneuver and night flight evaluations. The flat plate canopy had more structural beam obstructions than the standard AH-1G canopy, but it also provided more area for lateral head movement because of the wider separation of the side

Photo B. K-747 Rotor to Pylon Fairing Interference

panels near the top of the canopy. Lateral and downward field of view to either side was slightly improved over the AH-1G because of the greater freedom of head movement. The horizontal beam above the forward canopy panel was an obstruction to the pilot's forward field of view in level flight. The area directly below this structural beam was further obscured by the copilot/gunner's helmet. These combined obstructions required the pilot to sideslip the helicopter during approaches and level NOE flight to obtain an adequate forward field of view. Forward field of view was also obstructed by the vertical structural beams at the pilot's 11 and 1 o'clock positions. These vertical beams obstructed the pilot's forward field of view during maneuvering NOE flight. Additionally, the horizontal cross-beam between the top panels of the canopy obstructed the pilot's forward field of view during level flight accelerations. The obstruction to the pilot's forward field of view due to the location of the modified flat plate canopy structural beams is a shortcoming.

Cockpit Evaluation

Night Vision Goggle Switch:

48. The pilot NVG switch is a two-position thumb switch located on the top right of the cyclic grip (fig. B). The NVG switch is not guarded and is easily activated to the forward or NVG position. Actuation of this switch dims the pilot warning, caution, and instrument lights to a level that prevents daylight detection of illumination. The copilot/gunner NVG switch is located on the miscellaneous control panel and serves the same function for the forward cockpit lighting. The possibility exists wherein both NVG switches could be inadvertently actuated during daylight operations, preventing either pilot from rapidly detecting a fault warning. A more probable situation of undetected fault warning may occur during daylight TOW missile operations when the copilot/gunner is concentrating his attention on the telescopic sight unit. In this case, the pilot's inadvertent actuation of the cyclic-mounted NVG switch may preclude the rapid detection of a fault warning. Such an occurrence would delay or prevent the pilot's initiation of immediate and appropriate corrective action. The design/location of the pilot NVG switch is conducive to inadvertent deactivation of the visual fault warning system and is a deficiency.

Alternating Current/Armament Circuit Breakers:

49. The TOW power, turret control, and helmet sight subsystem circuit breakers are the pop-out, push-to-reset breakers located on the AC/armament circuit breaker panel directly below the pilot collective pitch control stick. This panel is located further rearward than on previous AH-1 helicopters. The location of these circuit breakers directly below the pilot collective stick hampered the pilot's ability to

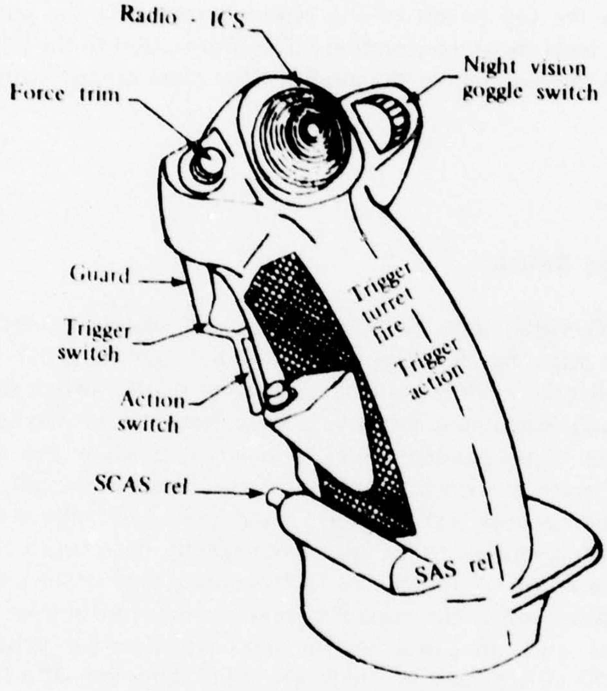


Figure B. Pilot Cyclic Grip

see and identify popped circuit breakers. Additionally, if the pilot were required to activate one of these circuit breakers in flight, he would have to release the collective and activate the breaker with his left hand while reaching around the collective stick. This action could cause inadvertent collective inputs. The poor or not easily accessible location of the AC/armament circuit breaker is a shortcoming.

Pilot Wing Stores Jettison Switch:

50. The pilot wing stores jettison switch was a guarded thumb button located on the collective stick control panel. The guard for this switch consisted of a raised circular shield that extended 1/2 inch above the control panel surface and was located approximately 1/4 inch forward of the power turbine rpm INCR/DECR switch. The proximity of the jettison switch guard to the power turbine beep trim switch hampered the pilot's control of power turbine speed. The lack of adequate separation between the wing stores jettison switch guard and the power turbine rpm INCR/DECR switch is a shortcoming.

Direct Current-Powered Instruments:

51. The production AH-1S helicopter torquemeters, turbine gas temperature indicators, dual tachometers, gas producer tachometers, and the engine and transmission pressure/temperature indicators are all powered by the 28-VDC essential bus. The emergency procedures in the operator's manual (ref 4, app A) for an in-flight electrical fire require the pilot to turn off both the generator and battery and land immediately. If these procedures are followed, the above instruments will be rendered inoperative prior to landing. The following CAUTION has been submitted for inclusion in chapter 9 of the operator's manual:

CAUTION

> Turning both generator and battery switches to the OFF position will render the following instruments inoperative: torquemeters, turbine gas temperature indicators, dual tachometers, gas producer tachometers, and engine and transmission oil pressure/temperature indicators.

Gunner Canopy Door Latch:

52. When the YAH-1S helicopter was allowed to heat soak for several hours in the sun on an 80°F day, the gunner canopy door expanded and would not close. The aft striker door latch was machined down approximately 1/8 inch to provide the clearance necessary. This clearance was adequate for subsequent testing at temperatures to 95°F. The adequacy of the door latch to maintain a tight fit during cold weather was not determined. The inability to close the gunner canopy door

due to expansion during hot weather is a shortcoming. An Equipment Performance Report was submitted on this shortcoming.

Airspeed System Calibration

53. The pitot tube was relocated from the fuselage nose position on the AH-1G to the main transmission upper pylon cowling on the AH-1Q and AH-1S aircraft. Airspeed calibration tests were conducted to determine the position error of the YAH-1S airspeed system at the conditions listed in table 1, utilizing the techniques described in appendix D. Results of the tests are presented in figures 23 and 24, appendix E.

54. In level flight and the clean configuration, the ship's position error was nonlinear and varied from zero at 105 KIAS to -5 knots at 30 KIAS and to +10 knots at 150 KIAS. In climbing flight at MCP, 8-TOW configuration, the variation of airspeed position error with airspeed was slightly nonlinear and varied from a +6-knot error at 120 KIAS to a +19-knot error at 72 KIAS. The trends are similar to the AH-1Q but the magnitude of the errors is increased. The maximum allowable error for any flight condition listed in military specification MIL-I-6115A (ref 18, app A) is ±6 knots. The detail specification does not require the AH-1S to meet the requirements of MIL-I-6115A; however, USAAEFA considers it to be a reasonable standard. The large airspeed position errors for high-speed level flight and high power climbing flight are a shortcoming.

55. In autorotational descents in the 8-TOW configuration the ship's system position error was a constant -6 knots at airspeeds between 34 and 106 KIAS. During stabilized autorotations at 40 KCAS, using the boom system as a reference, the ship's system varied from zero to 34 KIAS. Due to this large variation in position error, the ship's airspeed system is unusable during autorotations at airspeeds below 34 KIAS.

56. When trimmed for coordinated flight (ball-centered) at low airspeeds, the YAH-1S had an inherent sideslip that varied from 4 degrees right at 60 KCAS to approximately 25 degrees right at 30 KCAS. During low-speed flight at right sideslip angles greater than the inherent sideslip, large airspeed position errors were noted. For trimmed airspeeds of 40 and 60 KCAS, the airspeed position error was in excess of 10 knots for sideslip angles of 20 degrees right. The magnitude of the position errors makes the ship's airspeed system unreliable for low-speed maneuvering flight. During NOE flight, using the calibrated airspeed boom system as a reference, airspeed position errors in excess of 30 knots were noted. The lack of an airspeed system that is accurate during low-speed maneuvering flight is a shortcoming.

CONCLUSIONS

GENERAL

57. Within the scope of this evaluation, the following conclusions relative to the modified flat plate canopy and K-747 rotor blade installation on the YAH-1S helicopter have been made.

a. The increase in Δf_e due to the modified flat plate canopy is approximately 3 ft^2 (para 10).

b. The Δf_e due to the 8-TOW configuration is 5 ft^2 (para 11).

c. The Δf_e due to changes in cg location is reduced when compared to the AH-1G (para 11).

d. Autorotational V_{min} R/D is 61 KCAS (para 13).

e. Autorotational V_{max} glide is 93 KCAS (para 13).

f. Control system characteristics are comparable to those of other AH-1 series helicopters (para 16).

g. The modified flat plate canopy vibration characteristics are significantly improved over previous flat plate canopy design (para 43).

h. Static K-747 rotor blade-to-pylon fairing interference is possible, but the probability of an in-flight occurrence appears to be remote (para 46).

i. Two deficiencies and nine shortcomings were noted.

DEFICIENCIES AND SHORTCOMINGS

58. The deficiencies listed below were identified during these tests and are listed in order of relative importance.

a. The high intensity of mirror images of both internal and external light sources on the modified flat plate canopy during night flight (para 38).

b. The design/location of the NVG switch is such that its inadvertent activation effectively deactivates the visual fault warning system (para 48).

59. The shortcomings listed below were identified during these tests and are listed in order of relative importance.

a. The weak directional stability near trim (para 25).

b. The weak side-force characteristics (para 27).

c. The obstruction to the pilot's forward field of view due to the location of the modified flat plate canopy structural beams (para 47).

d. The lack of an airspeed system that is accurate during low-speed maneuvering flight (para 56).

e. The large position errors for high-speed level flight and high power climbing flight (para 54).

f. The weak static longitudinal stability at cruise airspeeds (para 23).

g. The lack of adequate separation between the wing stores jettison switch guard and the power turbine rpm INCR/DECR switch (para 50).

h. The location of the AC/armament circuit breakers below the collective control (para 49).

i. The inability to close the gunner canopy door due to expansion when it was left open for a long period during hot weather (para 52).

RECOMMENDATIONS

60. The autorotational V_{min} R/D and V_{max} glide listed in the operator's manual should be retained (para 13).

61. The deficiencies identified during this evaluation must be corrected to safely accomplish the attack helicopter mission (para 58).

62. The shortcomings should be corrected in future revisions of the AH-1 series helicopters (para 59).

63. The following CAUTIONS should be included in the operator's manual (paras 13 and 51):

CAUTION

The ship's airspeed system provides unreliable information at airspeeds below 40 KIAS. Steady-state autorotation at airspeeds below 40 KIAS will result in excessive rates of descent and near-vertical descent angles.

CAUTION

Turning both generator and battery switches to the OFF position will render the following instruments inoperative: torquemeters, turbine gas temeprature indicators, dual tachometers, gas producer tachometers, and engine and transmission oil pressure/temperature indicators.

APPENDIX A. REFERENCES

1. Final Report, USAAEFA, Project No. 75-18, *Army Preliminary Evaluation, YAH-1Q Helicopter With a Flat Plate Canopy*, August 1975.

2. Letter, AVSCOM, DRSAV-EQI, 4 February 1977, subject: Test Request No. 77-04, Follow On Evaluation of AH-1S Helicopter Incorporating Flat Plate Canopy and Improved Main Rotor Blade (IMRB) K-747.

3. Test Plan, USAAEFA, Project No. 77-04, *YAH-1S Modified Flat Plate Canopy Evaluation*, March 1977.

4. Technical Manual, TM 55-1520-236-10, *Operator's Manual, Army Model AH-1S Helicopter, Final Draft*, 15 January 1977.

5. Technical Manual, TM 55-1520-234-10, *Operator's Manual, Army Model AH-1S Helicopter*, 17 November 1976.

6. Technical Manual, TM 55-1520-221-10, *Operator's Manual, Army Model AH-1G Helicopter*, 12 December 1975.

7. Final Report, US Army Aviation Systems Test Activity (USAASTA), Project No. 72-30, *Engineering Flight Test, AH-1G Helicopter With Model 212 Tail Rotor, Part II, Performance and Handling Qualities*, September 1973.

8. Letter, AVSCOM, DRSAV-EQI, 15 March 1977, subject: Safety of Flight Release for YAH-1S Production Prototype Helicopter S/N 70-16019, Equipped with Flat Glass Canopy and K-747 Improved Main Rotor Blades (MRB) or Standard Bell 540 MRB.

9. Military Specification, MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities; General Requirements For*, 7 September 1961, with Amendment 1, 3 April 1962.

10. BHT Detail Specification, No. 209-947-265, "Model AH-1S Helicopter," 13 August 1975.

11. Pamphlet, Army Materiel Command, AMCP 706-204, *Engineering Design Handbook, Helicopter Performance Testing*, 1 August 1974.

12. Flight Test Manual, Naval Air Test Center, FTM No. 102, *Helicopter Performance Testing*, 28 June 1968.

13. Flight Test Manual, Naval Air Test Center, FTM No. 101, *Helicopter Stability and Control*, 10 June 1968.

14. Final Report, USAASTA, Project No. 66-06, *Engineering Flight Test, AH-1G (HueyCobra) Phase D, Part I, Handling Qualities*, December 1970.

15. Final Report, USAAEFA, Project No. 74-33, *Army Preliminary Evaluation, YAH-1R Improved Cobra Agility and Maneuverability Helicopter*, May 1975.

16. Report, Kaman Aerospace Corporation, T-707, *Test Results of an Interference Investigation of the K-747-003 IMRB on the Whirl Test Stand*, 21 April 1977.

17. Report, Kaman Aerospace Corporation, T-706, *Test Results of Interference Investigation of the K-747-003 IMRB on AH-1G Helicopter*, 18 April 1977.

18. Military Specification, MIL-I-6115A, *Instrument Systems, Pitot Tube and Flush Static Port Operated; Installation of*, March 1951, with Amendment 3, 31 December 1960.

APPENDIX B. DESCRIPTION

GENERAL

1. The test helicopter, SN 70-16019, is an AH-1G helicopter modified to the production AH-1S configuration (ref 4, app A) and redesignated the YAH-1S. The fuselage modifications were primarily internal structural changes to strengthen the fuselage, tail boom, and cantilever wings to accept the higher stresses due to increased gross weight, engine power, and available tail rotor power. The cockpit instrument and control panels were also redesigned to accommodate new instruments and avionics. The emergency hydraulic accumulator system of the AH-1G has been replaced by an emergency hydraulic pump. Additionally, the standard AH-1G canopy has been replaced by a seven-plane geometry modified flat plate canopy. The side panels of the redesigned flat plate canopy (ref 1) are bulged approximately 1-1/8 inches. A descriptive drawing (fig. 1) and photographs (photos 1 and 2) of the fuselage and flat plate canopy are included in this appendix.

ENGINE

2. The T53-L-703 turboshaft engine is installed in the AH-1S helicopter. This engine employs a two-stage, axial-flow free power turbine; a two-stage, axial-flow turbine driving a five-stage axial and one-stage centrifugal compressor; variable inlet guide vanes; and an external annular combustor. A 3.2105:1 reduction gear located in the air inlet housing reduces power turbine speed to a nominal output shaft speed of 6600 rpm at 100 percent N_2. The engine reduction gearbox is limited to 1175 foot-pounds (ft-lb) torque for 30 minutes and to 1110 ft-lb torque for continuous operation. A T_7 interstage turbine temperature sensor harness measures interstage turbine temperatures and displays this information in the cockpit as TGT on the cockpit instruments.

TRANSMISSION AND TAIL ROTOR DRIVE

3. The main transmission has a 1290-shp limit for 30 minutes and a 1134-shp limit for continuous operation at a rotor speed of 324 rpm (100 percent N_R). The tail rotor drive system has a 260-shp transient limit for 4 seconds and a 187-shp limit for continuous operation.

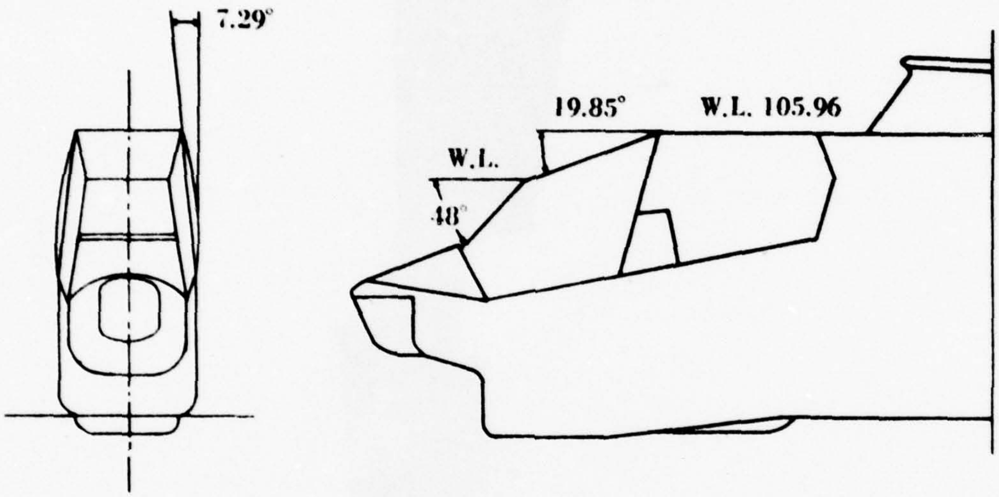


Figure 1. YAH-1S with Seven-Plane Geometry Modified Flat Plate Canopy.

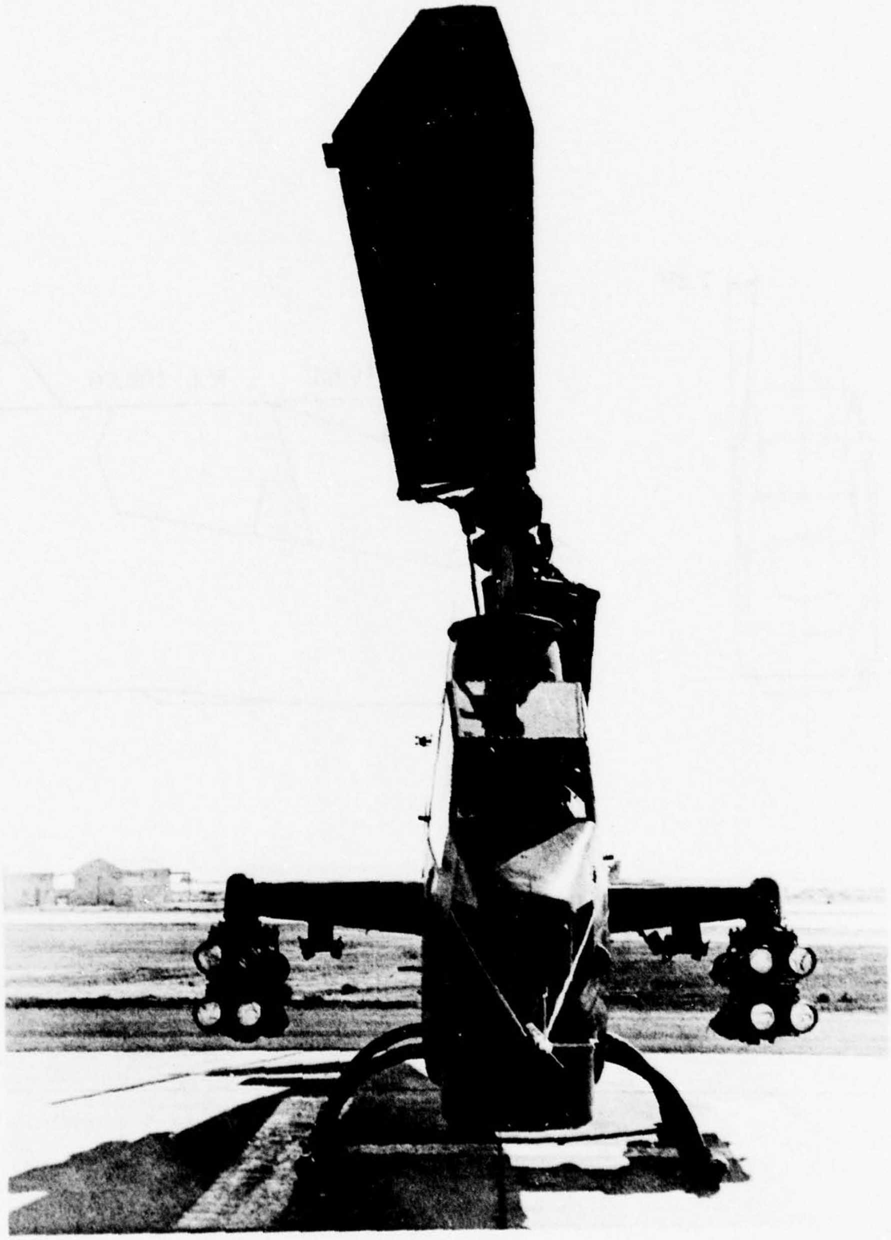


Photo 1. YAH-1S Front View

Photo 2. YAH-1S Front Quarter View

COCKPIT INSTRUMENT AND CONTROL PANELS

4. The cockpit instrument and instrument control panels have been redesigned in the production AH-1S to incorporate redesigned flight and system instruments and the AN/ARC 114-116 radios. An ID-2104/A attitude direction indicator and an ID-2103/A horizontal situation indicator have been incorporated in the flight instrument panel. The oil pressure and temperature indicators for both the engine and transmission systems have been combined into single instruments. Additionally, the engine torquemeters, TGT indicators, dual tachometers, and gas producer tachometers are now all powered through the 28-VDC essential bus. The fuel pressure indicator has been deleted in the production AH-1S configuration. Detailed descriptive drawings and photographs of the redesigned cockpits are included in the operator's manual (ref 4, app A).

EMERGENCY HYDRAULIC SYSTEM

5. The emergency hydraulic accumulator system of the AH-1G series helicopter has been replaced in the production AH-1S by an emergency hydraulic system which consists of an additional hydraulic reservoir and an electrically driven pump located below the main transmission. This system provides hydraulic pressure for boresighting of the turret and outboard wing pylons, as well as to the collective pitch controls in the event of a hydraulic flight boost system failure. The system is controlled by toggle switches in either cockpit station labeled EMER HYDR PUMP/BORESIGHT and hydraulic pressure will be supplied to the collective controls with one or both switches in the ON position. The system is electrically powered through the 28-VDC essential bus and with the battery as the sole source of power, approximately 5 minutes of pump operating time will be available.

MAIN ROTOR BLADES

6. The test aircraft was flown with BHT B-540 rotor blades and with KAC improved main rotor blades, designated K-747. The K-747 has a multicell filament-wound fiberglass spar, a nomex core afterbody, and a kevlar trailing edge spline, all of which is encased by a fiberglass skin. Cheek plates at the inboard end carry blade loads to an aluminum adapter which attaches the blade to the current AH-1 series hub.

7. The K-747 rotor has essentially the same diameter and equivalent solidity as the current B-540 system, although the blade planform has been changed. Blade twist has been increased and advanced airfoil shapes have been employed. The K-747 blade weight and stiffness distribution were designed to match the dynamic characteristics of the B-540 rotor. A 55-pound brass tip weight, integral to the spar, provides rotor inertial characteristics similar to the B-540 system. The constant chord section of the K-747 blade is 2.5 feet as compared to the 2.25-foot chord of the B-540 blade which is constant over the entire blade. The outer 15 percent of the K-747 blade is tapered in both thickness and planform. The planform taper

is trapezoidal, with a tip chord of 0.83 feet. The equivalent solidity of the K-747 is 0.0625, which is comparable to the 0.0651 solidity of the B-540 rotor.

8. The K-747 blade airfoil shape is based on a family of advanced airfoils developed by Boeing Vertol. For the outer 15 percent of the blade (*ie*, from r/R = 0.85 (85 percent blade radius station) out), the 8-percent thick Boeing Vertol VR-8 airfoil is used. From r/R = 0.25 to r/R = 0.67, the 12-percent thick Boeing Vertol VR-7 airfoil is used, with a linear transition between the 67-percent and 85-percent radius stations. From r/R = 0.25 station inboard, the blade is built up gradually by cheek plates. The leading edge becomes blunt and reaches a maximum thickness of 25 percent at the end of the blade at r/R = 0.18. The current AH-1 hub, which has its hub pin at r/R = 0.15, is retained. There is an attachment adapter fitting and drag brace between the pin and the end of the blade. Figure 2 presents a planform view and figure 3 a cross-section view of the K-747 blade configuration.

CONTROL SYSTEM

9. The control system of the AH-1S is basically the same as the AH-1G with two exceptions: the cable controls of the AH-1G antitorque system have been replaced by push-pull tubes and a collective rate limiter has been installed which limits collective control movement to 100 percent of full throw in 0.87 second.

10. A flight control rigging check performed prior to the test in accordance with the procedures outlined in TM 55-1520-234-20 demonstrated that the cyclic, collective pitch, and directional controls were within prescribed limits. The swashplate and tail rotor blade pitch angles are listed below.

Swashplate Angles (measured in control axis)

Control position:	
Full forward cyclic	13 deg fwd
Full aft cyclic	13 deg aft
Full left cyclic	9 deg left
Full right cyclic	8 deg right

Tail Rotor Blade Pitch Angles

Pedal position:	
Neutral (centered)	+3.75 deg
Left pedal	+19 deg
Right pedal	-12.5 deg

PRINCIPAL DIMENSIONS

11. Principal dimensional and general data concerning the YAH-1S helicopter are

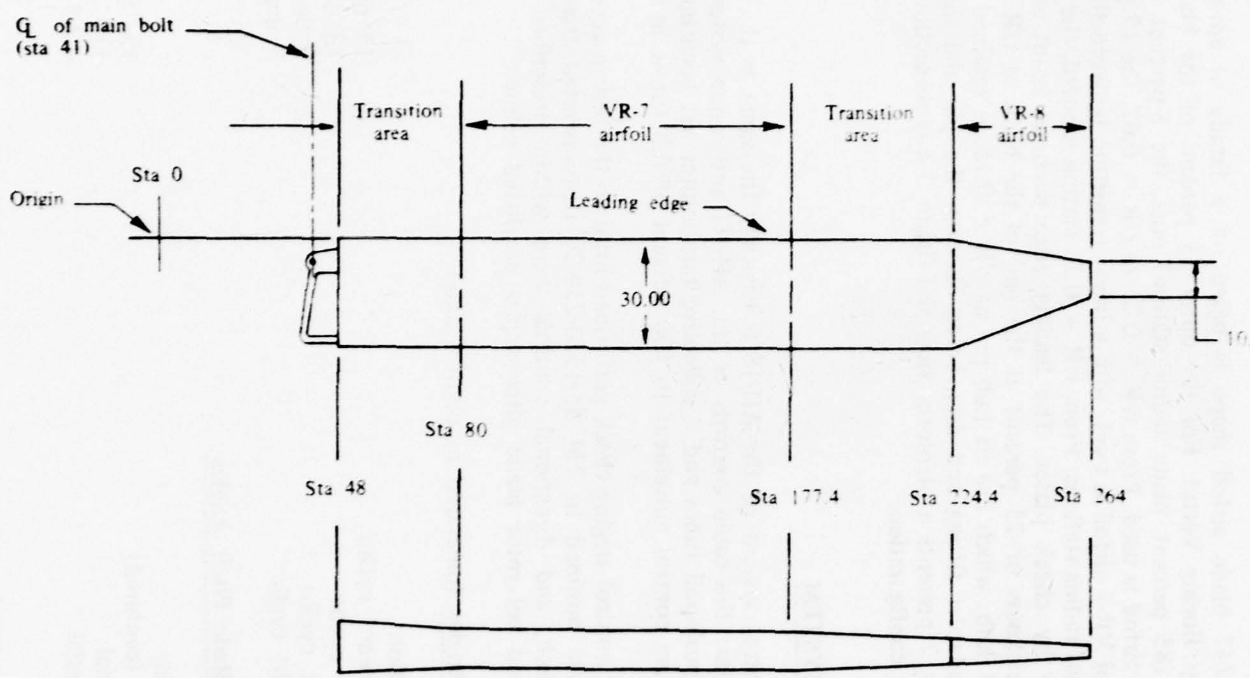
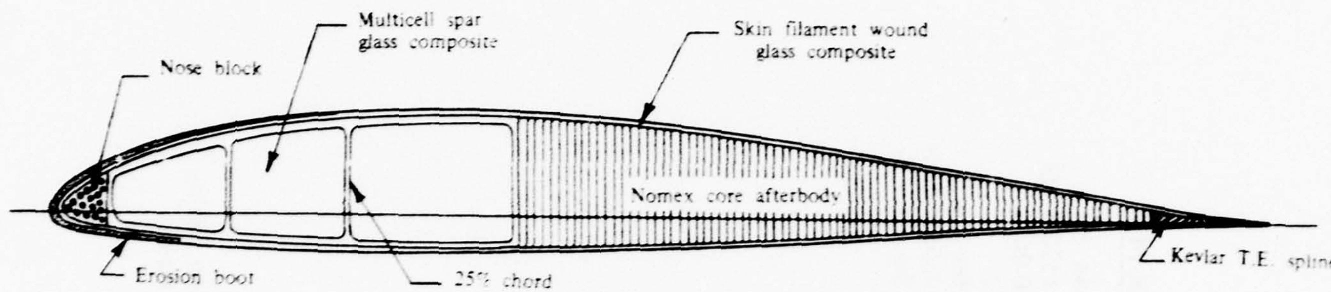


Figure 2. K-747 Blade Configuration.



Stations 66 through 177.4

Figure 3. K-747 Blade Cross-Section Structural Arrangement.

as follows:

Overall Dimensions

Length, rotor turning		52 ft, 11 in.
Height, tail rotor vertical		13 ft, 9.5 in.
Main Rotor	**K-747**	**B-540**
Diameter	44 ft	44 ft
Disc area	1520.5 ft^2	1520.5 ft^2
Solidity	0.0625	0.0651
Number of blades	2	2
Blade chord	See fig. 2	2.25 ft, constant
Blade twist	-0.556 deg/ft	-0.455 deg/ft
Airfoil	See para 8	9.33% thickness, special symmetrical section
Tail Rotor		
Diameter		8 ft, 6 in.
Disc area		56.75 ft^2
Solidity		0.1436
Number of blades		2
Blade chord, constant		11.5 in.
Blade twist		0.0 deg/ft
Airfoil		NACA 0018 at blade root, changing linearly to special cambered section of 8.27% of tip
Fuselage		
Length		45 ft, 2.2 in.
Height:		
To tip of tail fin		10 ft, 4 in.
Ground to top of mast		11 ft, 7 in.
Ground to top of transmission fairing		10 ft, 2 in.
Ground to bottom of chin turret		1 ft, 2 in.
Width:		
Fuselage only		3 ft, 0 in.
Engine cowling		3 ft, 6 in.
Skid gear tread		7 ft, 4 in.
Elevator:		
Span		6 ft, 2 in.
Area		25.2 ft^2

Airfoil	Inverted Clark Y
Vertical fin:	
Area	18.5 ft^2
Airfoil	Special cambered
Height	5 ft, 6 in.
Wing:	
Span	10 ft, 8.24 in.
Area	27.8 ft^2
Incidence	14 deg
Airfoil (root)	NACA 0030
Airfoil (tip)	NACA 0024

WEIGHT AND BALANCE

12. Aircraft weight and longitudinal and lateral cg were determined prior to testing. With fuel tanks drained and ballast boxes and instrumentation installed, aircraft weight was 6430 pounds with a longitudinal cg of 203.7 inches and a lateral cg of 0.2 inch right of center line.

13. Two cg locations, forward and aft, were utilized during performance testing in the 8-TOW configuration. A typical mission loading at design gross weight is shown in table 1.

Table 1. Weight and Balance for Typical Mission Loading Configuration.[1]

Item	Weight (lb)	Moment
Basic aircraft[2]	6,901	1,395,200
Oil (3.5 gal)	29	690
Pilot	200	27,000
Gunner	200	16,800
Fuel (252 gal JP-4)	1,638	327,850
M65 TOW launchers with 4 missiles (1 per wing)	672	135,200
2600 rounds 7.62mm (turret)	170	20,600
250 rounds 40mm	190	21,500
Gross weight	10,000	1,944,840

[1] 8-TOW with turret.
Typical mission authorized armament configuration 13 as per Figure 4-1, ref 4, app A.

[2] Basic aircraft weight computed from test aircraft basic weight (without test instrumentation) with installation of turret armament and XM129 grenade launcher.

APPENDIX C. INSTRUMENTATION

1. Instrumentation was installed in the test aircraft by USAAEFA. A test boom incorporating a swiveling pitot-static head and sideslip vane was mounted on the nose of the aircraft. The pitot-static source was located 7 feet forward of the nose of the aircraft. All instrumentation was calibrated and maintained by USAAEFA.

2. Parameters displayed in the test aircraft were as follows:

<u>Pilot Panel</u>

Airspeed (boom)
Airspeed (ship's system)
Altitude (boom)
Altitude (ship's system)
Main rotor speed
Engine torque
Measured gas temperature*
Gas generator speed*
Control position:
- Longitudinal
- Lateral
- Directional
- Collective

Center-of-gravity normal acceleration
Angle of sideslip

<u>Copilot/Engineer Panel</u>

Airspeed (boom)
Altitude (boom)
Fuel flow
Fuel used (totalizer)
Main rotor speed
Engine torque
Total air temperature

3. Engine torquemeter calibration is presented in figure 1. Airspeed calibration of the boom system for level, climbing, and autorotational flight is presented in figures 2 and 3.

*Standard ship's instrument

FIGURE 1

ENGINE TORQUEMETER CALIBRATION

T53-L-703 S/N LE 152642

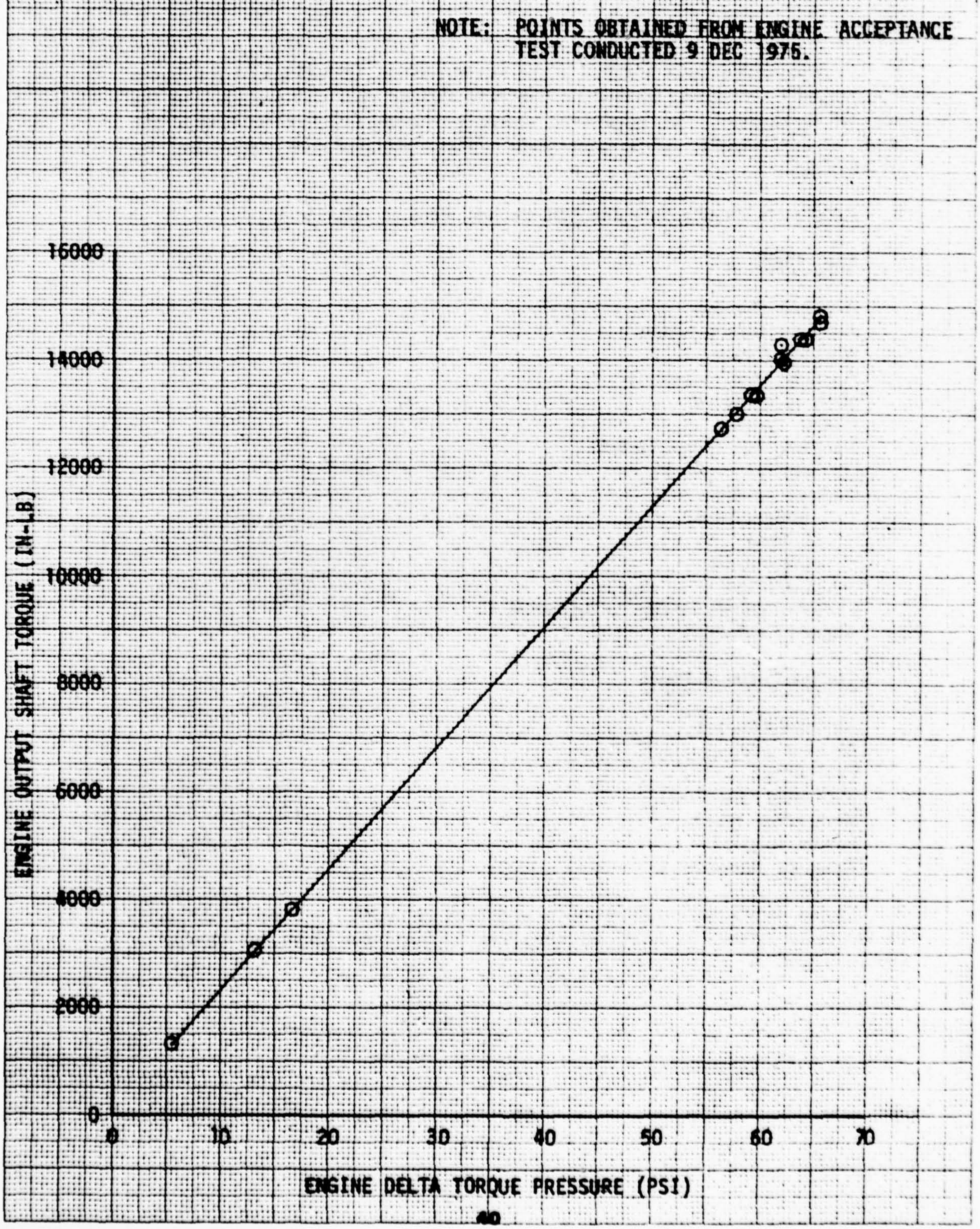


FIGURE 2
AIRSPEED CALIBRATION BOOM SYSTEM
YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN)	AVG CG LOCATION LAT (IN)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIGURATION
8320	199.8(AFT)	.2 RT	5220	11.5	324	CLEAN

NOTES: 1. DATA OBTAINED IN LEVEL FLIGHT
2. PACE METHOD UTILIZED
3. K-747 ROTOR INSTALLED
4. BALL-CENTERED TRIM CONDITION

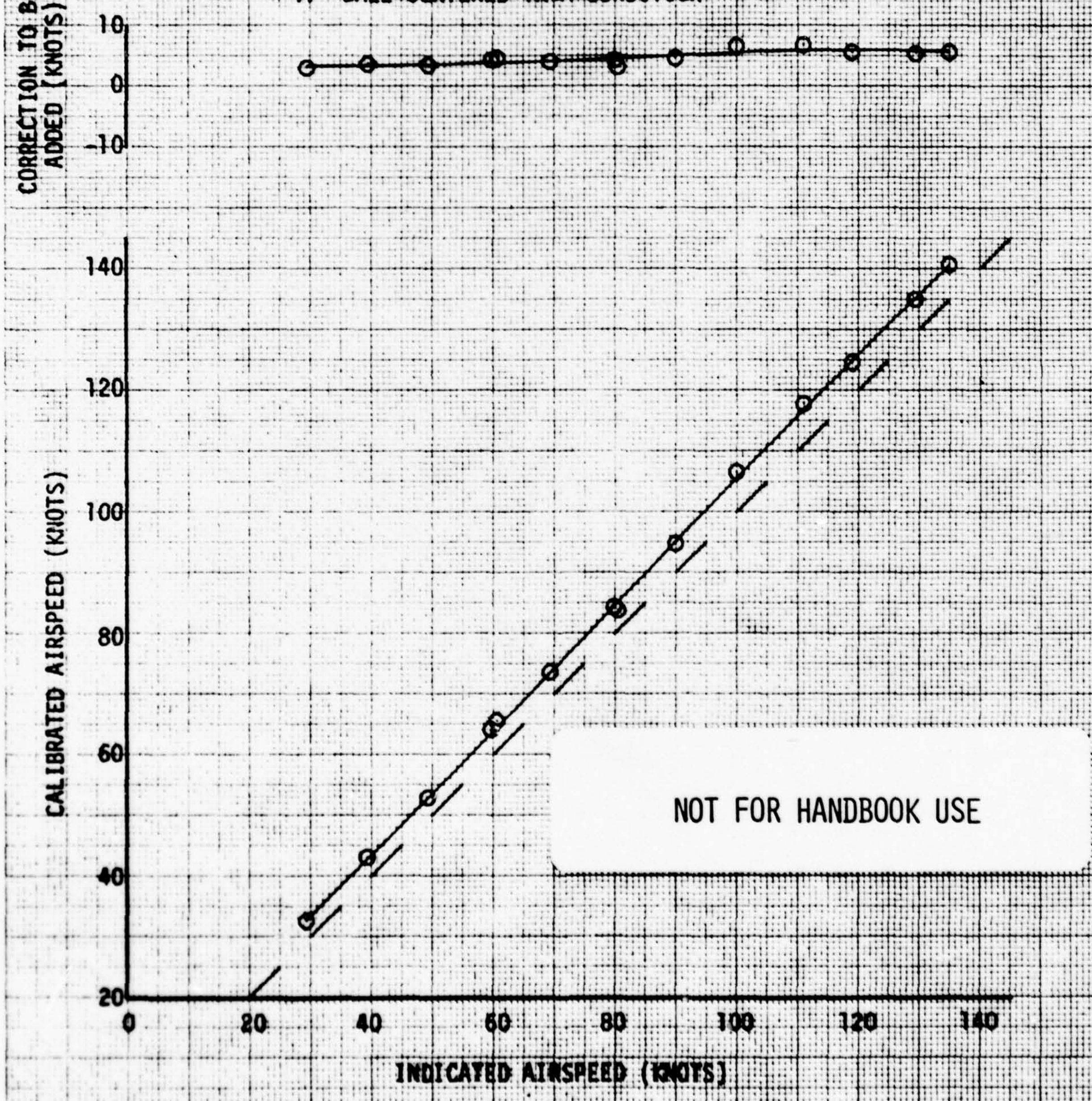
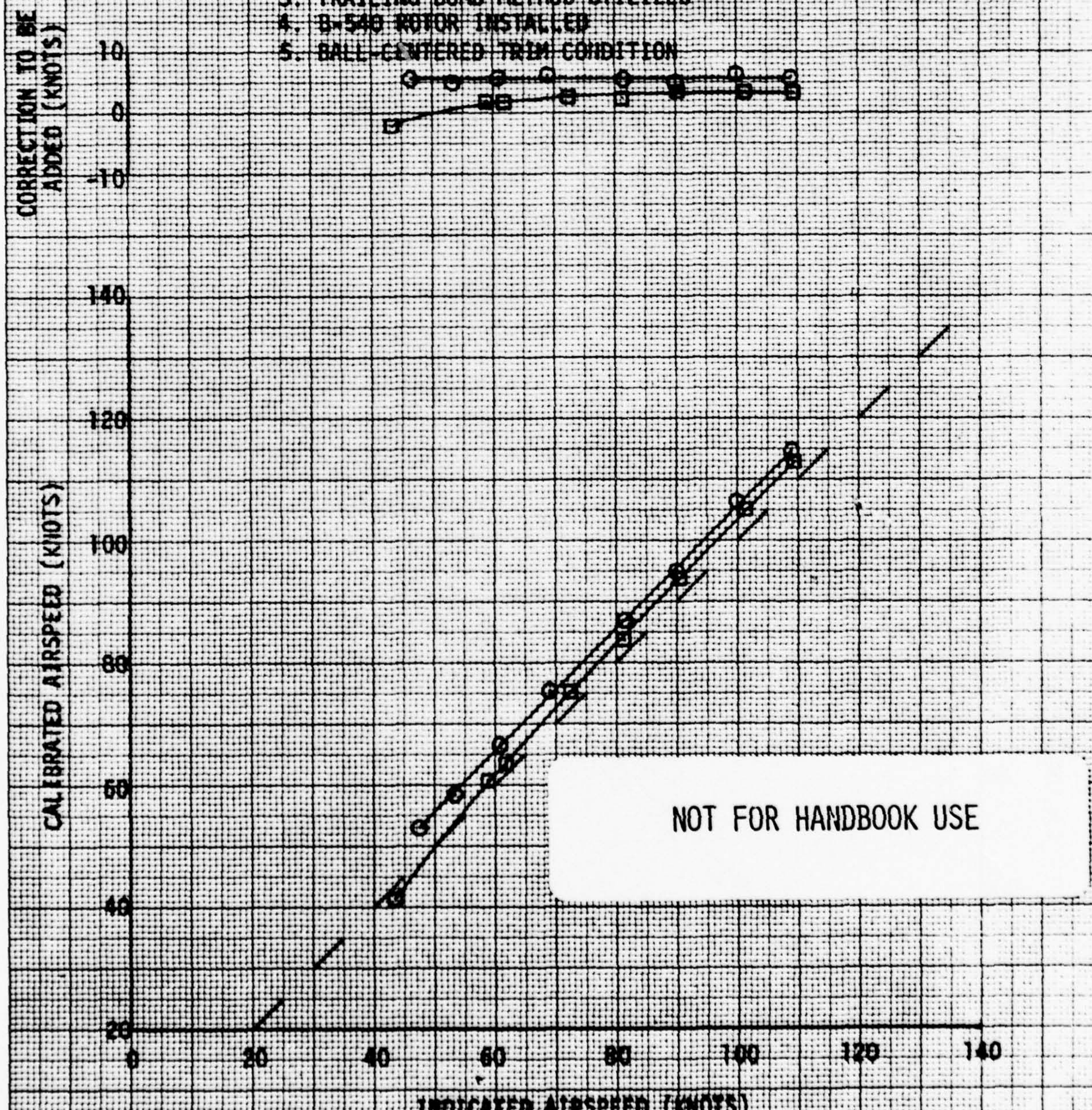


FIGURE 3
AIRSPEED CALIBRATION BOOM SYSTEM
YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIGURATION
9340	192.7(FWD)	.2 RT	5020	10.5	324	8-TOW

NOTES:
1. ○ DATA OBTAINED IN CLIMBING FLIGHT
2. □ DATA OBTAINED IN AUTOROTATIONAL FLIGHT
3. TRAILING BOMB METHOD UTILIZED
4. B-540 ROTOR INSTALLED
5. BALL-CENTERED TRIM CONDITION



APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

TEST TECHNIQUES

Weight and Balance

1. Aircraft weight and longitudinal and lateral cg were determined prior to testing. Two aircraft weighings were accomplished: the first with full fuel, ballast boxes, and aircraft test instrumentation and the second with all fuel drained. The first weight with full fuel was 8105 pounds with a longitudinal cg of 202.5 inches. The second weight with fuel drained was 6430 pounds with a longitudinal cg of 203.7 inches. The lateral cg for both weighings was 0.2 inch to the right of center line.

2. For all flights with external stores, the configuration consisted of two TOW missile launchers of two tubes each located on each outboard wing stores location (8-TOW configuration). The inboard wing stores locations were not utilized during testing. Ballast weights were installed at various fuselage stations to achieve desired gross weight/cg locations.

3. The fuel load for each test flight was determined prior to engine start and after engine shutdown. Total fuel load was determined by measuring the fuel specific gravity and temperature, and by using an external sight gage on the fuel cell to determine fuel volume. This sight gage was calibrated by leveling the helicopter through its longitudinal and lateral axes and noting the readings on the externally attached sight gage as fuel was drained in 5-gallon increments. Fuel used in flight was recorded by a calibrated fuel-used system and the final fuel-used reading following engine shutdown was cross-checked with the sight gage readings following each flight. The maximum usable fuel load was determined to be 252 gallons.

Level Flight Performance

4. Level flight performance parameters were determined utilizing the constant weight-to-density ratio (W/σ) method described in AMCP 706-204 (ref 9, app A). This method allows the entire flight to be flown at a constant value of the nondimensional parameter C_T, defined in paragraph 18. The aircraft was stabilized at zero sideslip at airspeeds between 40 KIAS and V_H, as limited by either engine power available or the maximum continuous transmission limit. The altitude for each test point was determined from current aircraft weight and ambient air density (determined from pressure altitude and ambient temperature). All test points were flown at a main rotor speed of 324 rpm. The helicopter was flown for a minimum of 2 minutes at each stabilized test condition.

Autorotational Descent Performance

5. Autorotational descent performance tests were conducted by stabilizing in an autorotational descent at constant airspeed and rotor speed at zero degree sideslip. Rotor speed was maintained at 324 rpm by adjusting collective position. Rate of descent was determined by recording time to descend through 1000 feet of altitude at varying increments of airspeed.

Control System Characteristics

6. Tests were conducted with the aircraft in a static condition on the ground, utilizing external power sources to pressurize both hydraulic flight control systems. Breakout forces (including friction) were measured by recording the force required to initiate first movement on the control position indicator. Force gradients were determined by displacing the control from a trim position at a rate of 0.1 to 0.15 inch per second and recording the forces applied and the stick displacemnt.

Control Positions in Trimmed Forward Flight

7. Control positions in trimmed forward flight were evaluated in conjunction with level flight performance tests. Data were obtained by stabilizing at zero sideslip at 10-knot increments, trimming control forces to zero, and recording control position.

Collective-Fixed Static Longitudinal Stability

8. Data were obtained by trimming the aircraft in ball-centered level flight at the desired airspeed and securing the collective control in that position. Airspeed was then varied ±20 knots from trim in 5-knot increments, utilizing the cyclic and directional controls only, and allowing altitude to vary as necessary. Control positions were recorded at each airspeed.

Static Lateral-Directional Stability

9. Tests were conducted in level flight by trimming the aircraft at the desired airspeed and securing the collective control. Data were obtained by varying sideslip angle incrementally to the limits of the sideslip envelope. Collective position, airspeed, and aircraft ground track were held constant and altitude allowed to vary as required. Control positions and aircraft attitude were recorded at each stabilized point.

Maneuvering Stability

10. Maneuvering stability tests were accomplished by initially stabilizing the helicopter in zero sideslip climbing flight near MCP at the desired airspeed and recording the trim condition. Load factor was then increased by stabilizing the helicopter at increasing bank angles in left and right turns. Airspeed and collective

were maintained constant and altitude allowed to vary. Symmetrical pull-ups and pushovers were conducted by alternately climbing and diving the helicopter to achieve varying normal accelerations (g) while the aircraft was passing through the trim altitude at the desired airspeed. Sudden pull-ups were conducted by rapidly displacing the longitudinal control aft, using various magnitudes of displacement. Zero sideslip was maintained throughout all the maneuvers.

Dynamic Stability

11. Tests were initiated in ball-centered level flight. Data were qualitatively obtained by evaluating the aircraft motions that resulted from pulse-type inputs about the longitudinal, lateral, and directional axes. Each input was accomplished by rapidly displacing the particular control approximately 1 inch from trim, holding in this position for 0.5 second, then rapidly returning to the trim position and holding until aircraft motions were damped or corrective action became necessary. All controls other than the input control remained fixed during the test. Additional lateral-directional characteristics were evaluated by returning the controls to level flight trim from a sideslip condition and noting the subsequent aircraft motions. Long-term dynamic response in forward flight was observed by displacing the aircraft from the trim airspeed using longitudinal cyclic. When an airspeed change of 10 to 15 knots was achieved, the control was returned to the trim position and held fixed at trim while the response of the aircraft was observed.

Simulated Sudden Engine Failures

12. Tests were initiated in ball-centered level flight by rapidly closing the throttle to the flight-idle position to simulate a loss in power. Following the simulated engine failure, all flight controls were held fixed until collective application was necessary to maintain rotor speed within established limits. Aircraft response subsequent to a sudden engine failure and the capability of the aircraft to transition safely into power-off autorotation were qualitatively evaluated.

Vibration Characteristics

13. Aircraft and canopy vibrations were qualitatively evaluated throughout the test program. Noise, visual cues, and touch were used as criteria to aid in evaluating canopy vibrations and determining vibration amplitude.

Pitot-Static System Calibration

14. Calibration of both the ship and boom airspeed systems was accomplished in level, climbing, and autorotational flight. Computation of the position error of the boom altitude system was also accomplished in level flight by using the boom airspeed position error and assuming all this error is introduced at the static ports. Position error determination was attained in level flight by the pace aircraft method, and in MCP climbs and autorotational descents with a calibrated trailing bomb. The procedure utilized during the pacer method was for the test aircraft

to stabilize at the desired condition, followed by the calibrated pace aircraft stabilizing on the test aircraft. Once this was achieved and the relative motion between the two aircraft was zero, data from both aircraft were recorded. Use of the calibrated trailing bomb involved stabilizing at the desired condition and simultaneously recording data from the test aircraft and the trailing bomb. In all flight regimes, data were obtained by stabilizing in ball-centered flight in 10-knot increments throughout the desired airspeed range.

DATA ANALYSIS METHODS

Nondimensional Method

15. Helicopter performance was generalized through the use of nondimensional coefficients. The test results obtained at specific test conditions were used to define performance at conditions not tested. The following nondimensional coefficients were used.

$$\text{Coefficient of power } (C_P) = \frac{SHP(550)}{\rho A(\Omega R)^3} \quad (1)$$

$$\text{Coefficient of thrust } (C_T) = \frac{GW}{\rho A(\Omega R)^2} \quad (2)$$

$$\text{Advance ratio } (\mu) = \frac{V_T(1.6878)}{\Omega R} \quad (3)$$

$$\text{Advancing blade tip Mach number } (M_{tip}) = \frac{(V_T) + (\frac{\Omega R}{1.6878})}{a} \quad (4)$$

Where:

SHP = Engine output shp

ρ = Air density (slug/ft^3)

A = Main rotor disc area (ft^2)

Ω = Main rotor angular velocity (radian/sec)

GW = Gross weight (lb)

V_T = True airspeed (kt)

a = Speed of sound (kt) = $661.48 \sqrt{\theta}$

Temperature ratio $(\theta) = \dfrac{\text{OAT} + 273.15}{288.15}$

OAT = Ambient air temperature (°C) corrected for adiabatic temperature rise

True airspeed (V_T) was calculated using calibrated airspeed (V_{CAL}) and density ratio as follows.

$$V_T = \frac{V_{CAL}}{\sqrt{\sigma}} \qquad (5)$$

Where:

$$\sqrt{\sigma} = \sqrt{\frac{\rho}{0.0023769}}$$

Values of airspeed and altitude used throughout this analysis were corrected for boom system position error determined from the pitot-static system calibration.

Power-Required Determination

16. Engine output shaft torque was determined by measuring differential torquemeter output pressure and applying the individual engine torquemeter conversion obtained from a least squares linear regression analysis of the engine acceptance data. The output shp was determined from the engine's output shaft torque and rotational speed by the following equation.

$$SHP = \frac{(2\pi)(N_E)(Q)}{396{,}000} \qquad (6)$$

Where:

N_E = Engine output shaft rotational speed (rpm) = $20.383(N_R)$

N_R = Main rotor rotational speed (rpm)

Q = Engine output shaft torque (in.-lb)

Level Flight Performance

17. Level flight performance was determined by using equations 1, 2, and 3. Each speed power was flown at a predetermined C_T with rotor speed held constant. To maintain the ratio of gross weight to air density ratio (W/σ) constant, altitude was increased as fuel was consumed. Test-day level flight power was corrected to standard-day conditions using the following relationship.

$$SHP_s = SHP_t \left(\frac{\rho_s}{\rho_t}\right) \qquad (7)$$

Where:

s = Standard day

t = Test day

18. Curves defined by the power required as a function of airspeed were plotted as Cp versus μ for a constant value of C_T. These curves were then joined by lines of constant μ to form a carpet plot. The reduction of this carpet plot into a family of curves, C_T versus Cp, for constant μ value allows determination of the power required as a function of airspeed for any value of C_T.

19. The specific range (NAMPP) data were derived from the test level flight power required and fuel flow. All level flight performance shp and fuel flow data were referred by ambient atmospheric conditions as follows.

$$SHP_{REF} = \frac{SHP_t}{\delta_a \sqrt{\theta_a}} \qquad (8)$$

$$W_{f_{REF}} = \frac{W_{f_t}}{\delta_a \sqrt{\theta_a}} \qquad (9)$$

Where:

Pressure ratio (δ_a) =

Hp = Pressure altitude (ft)

A mathematical curve fit was subsequently applied to this referred data and was used as the basis for all fuel flow computations. Standardized fuel flow was obtained from this curve. The following equation was used for determination of NAMPP.

$$\text{NAMPP} = \frac{V_T}{W_{f_s}} \qquad (10)$$

Where:

W_{f_s} = Standard-day fuel flow (lb/hr)

20. The tip Mach number of the advancing blade during level flight was determined using equation 4.

21. Changes in f_e due to change in aircraft configuration and cg were calculated using the following equation.

$$\Delta f_e = \frac{2(\Delta C_p)(A)}{\mu^3} \qquad (11)$$

Where:

ΔC_P = Change in coefficient of power at constant C_T and μ

Autorotational Descent Performance

22. Autorotational descent performance data were acquired at various stabilized airspeeds with constant rotor speed. Vertical speed was determined by measuring the time required to descend through 1000 feet pressure altitude. The tapeline rates of descent were calculated by the following equation.

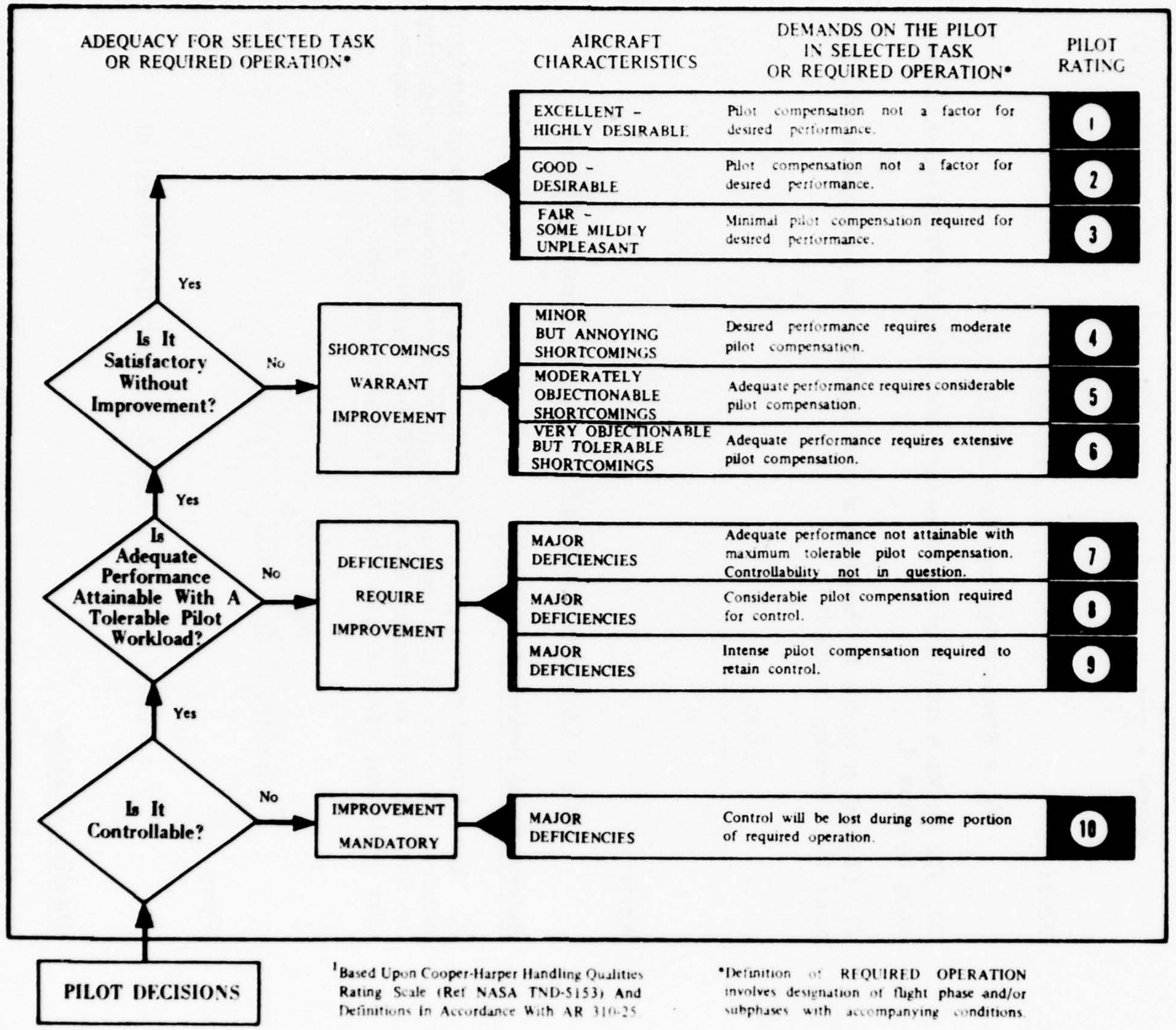
$$R/D_{tapeline} = \frac{dH_P}{dt} \frac{OAT_t + 273.15}{OAT_s + 273.15} \qquad (12)$$

Where:

$\frac{dH_P}{dt}$ = Change in pressure altitude per unit time (ft/sec) dt

Handling Qualities

23. Handling qualities data were evaluated using standard test methods described in reference 11, appendix A. Handling qualities ratings were quantified using figure 1.



[1] Based Upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND-5153) And Definitions In Accordance With AR 310-25.

*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions.

Figure 1. Handling Qualities Rating Scale.

APPENDIX E. TEST DATA

INDEX

FIGURE 1

NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE

YAH-1S USA S/N 70-16019

NOTES: 1. B-TOW CONFIGURATION
2. LONGITUDINAL CENTER OF GRAVITY = 192.5 IN. (FWD)
3. LATERAL CENTER OF GRAVITY = 0.2 IN. RT
4. ROTOR SPEED = 324 RPM
5. POINTS OBTAINED FROM FIGURES 4 THROUGH 9
6. B-540 ROTOR INSTALLED
7. ZERO SIDESLIP TRIM CONDITION

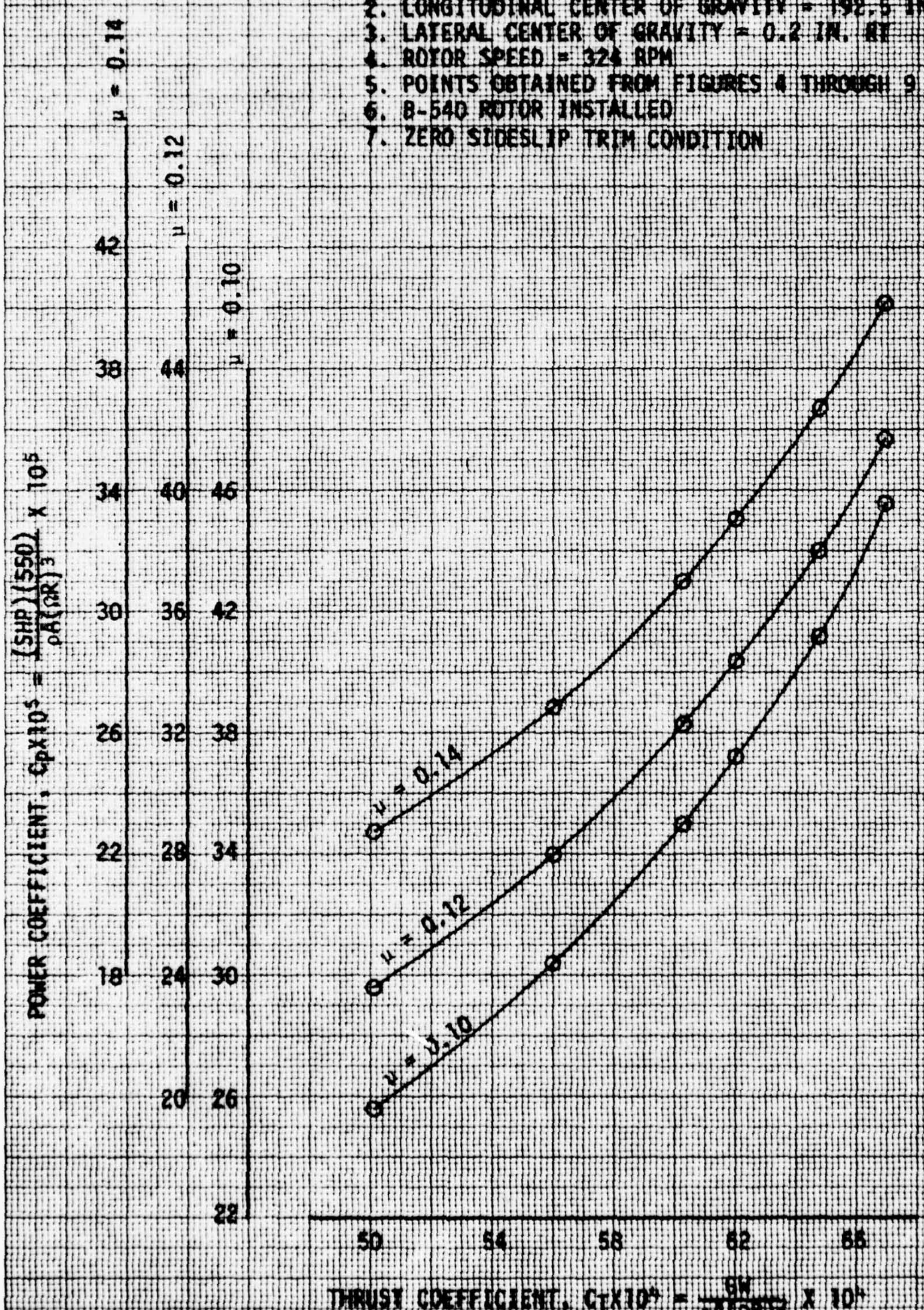


FIGURE 2

NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE

YAH-1S USA S/N 70-16019

NOTES:
1. 8-TOW CONFIGURATION
2. LONGITUDINAL CENTER OF GRAVITY = 192.5 IN. (FWD)
3. LATERAL CENTER OF GRAVITY = 0.2 IN. RT
4. ROTOR SPEED = 324 RPM
5. POINTS OBTAINED FROM FIGURES 4 THROUGH 9
6. B-540 ROTOR INSTALLED
7. ZERO SIDESLIP TRIM CONDITION

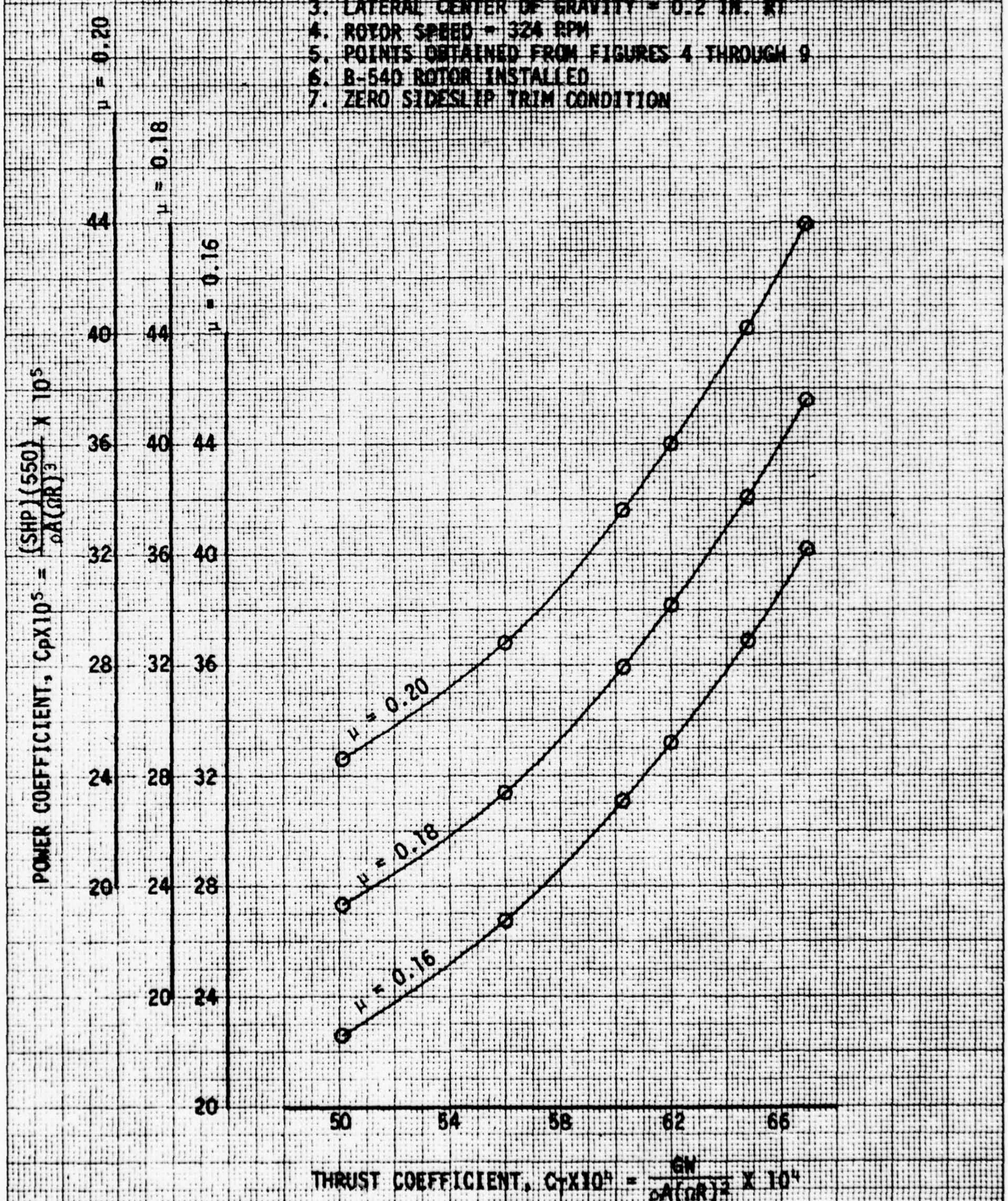


FIGURE 3

NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE

YAH-1S USA S/N 70-16019

NOTES:
1. 8-TOW CONFIGURATION
2. LONGITUDINAL CENTER OF GRAVITY = 192.5 IN. (FWD)
3. LATERAL CENTER OF GRAVITY = 0.2 IN. RT
4. ROTOR SPEED = 324 RPM
5. POINTS OBTAINED FROM FIGURES 4 THROUGH 9
6. B-540 ROTOR INSTALLED
7. ZERO SIDESLIP TRIM CONDITION

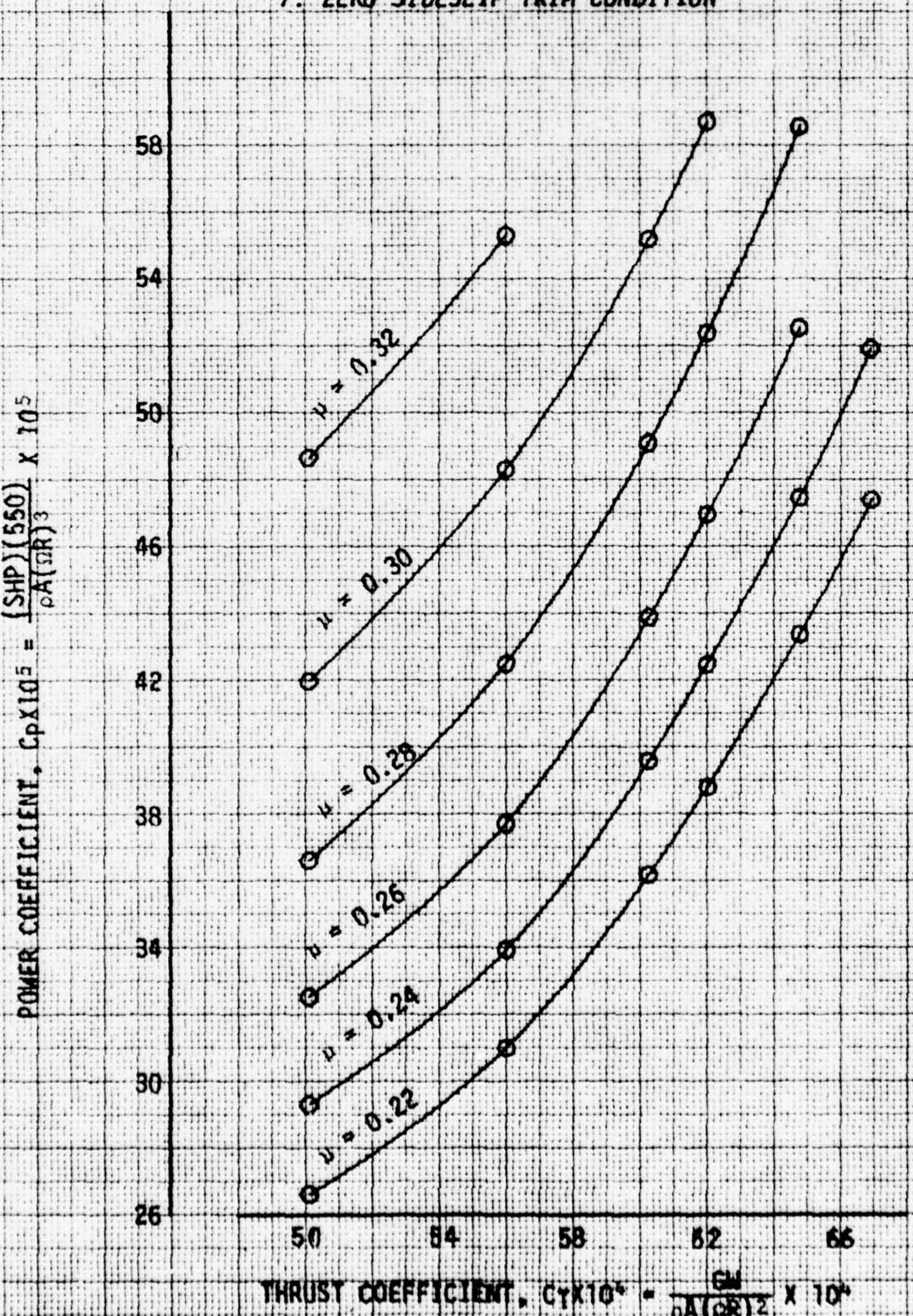


FIGURE 4
LEVEL FLIGHT PERFORMANCE
YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
8780	192.4(FWD)	0.2 RT	4680	17.5	324	0.005012	8-TOW

NOTES: 1. B-540 ROTOR INSTALLED
2. ZERO SIDESLIP TRIM CONDITION

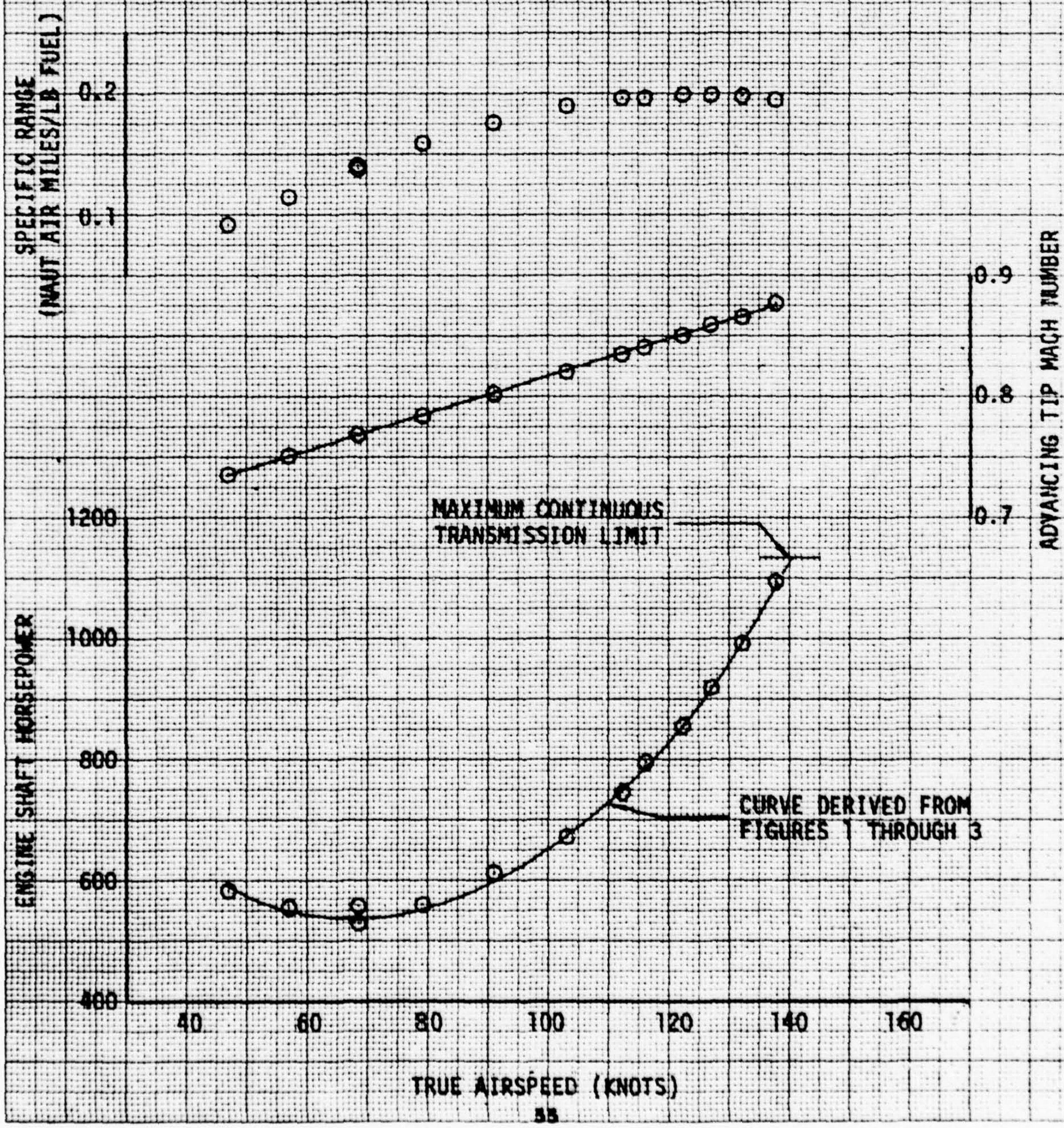


FIGURE 5
LEVEL FLIGHT PERFORMANCE
YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
9200	192.6(FWD)	0.2 RT	6800	13.5	324	0.005602	8-TOW

NOTES: 1. B-540 ROTOR INSTALLED
2. ZERO SIDESLIP TRIM CONDITION

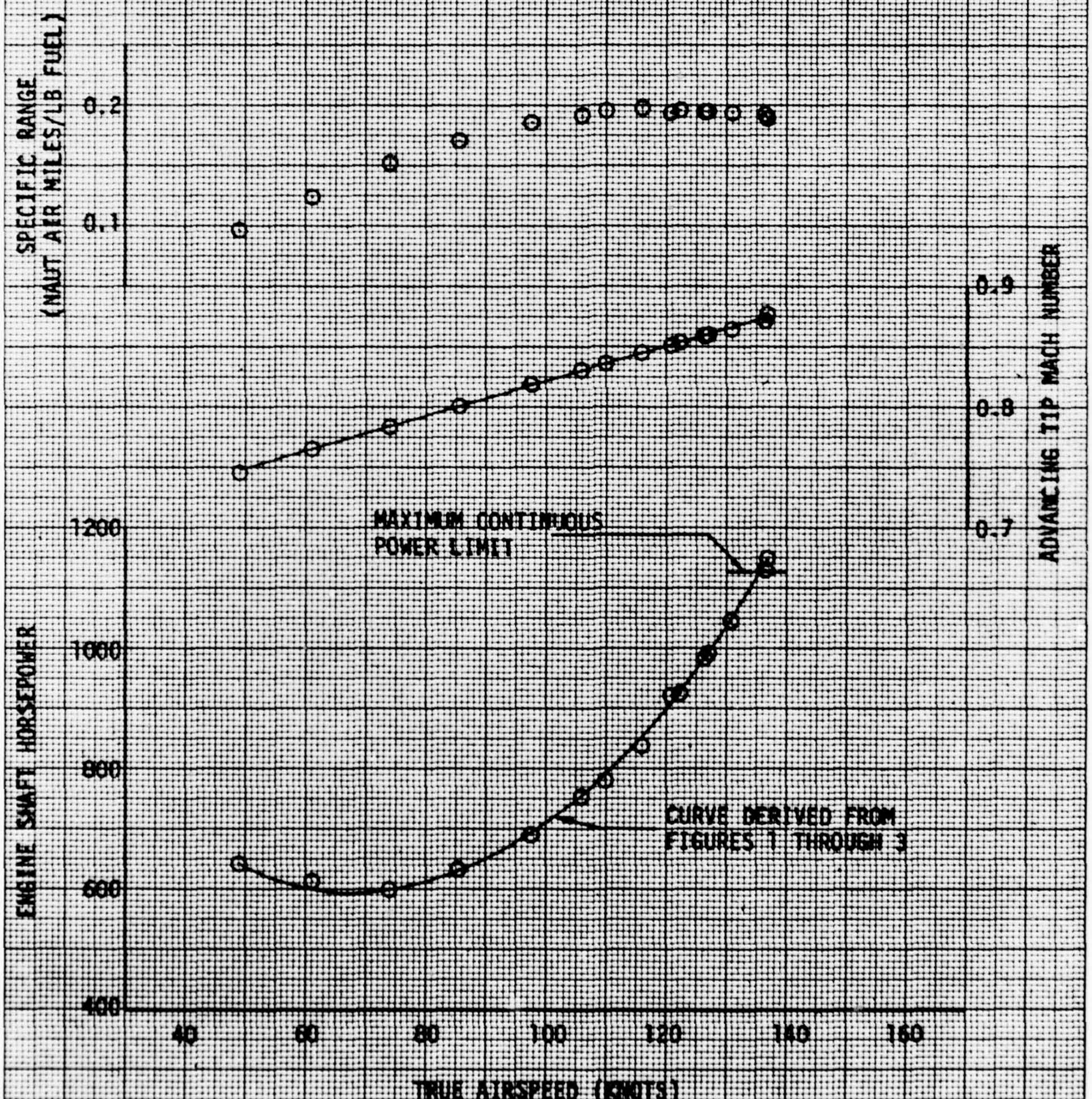


FIGURE 6
LEVEL FLIGHT PERFORMANCE
YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
9180	192.6(FWD)	0.2 RT	9240	6.5	324	0.006026	B-TOW

NOTES: 1. B-540 ROTOR INSTALLED
2. ZERO SIDESLIP TRIM CONDITION

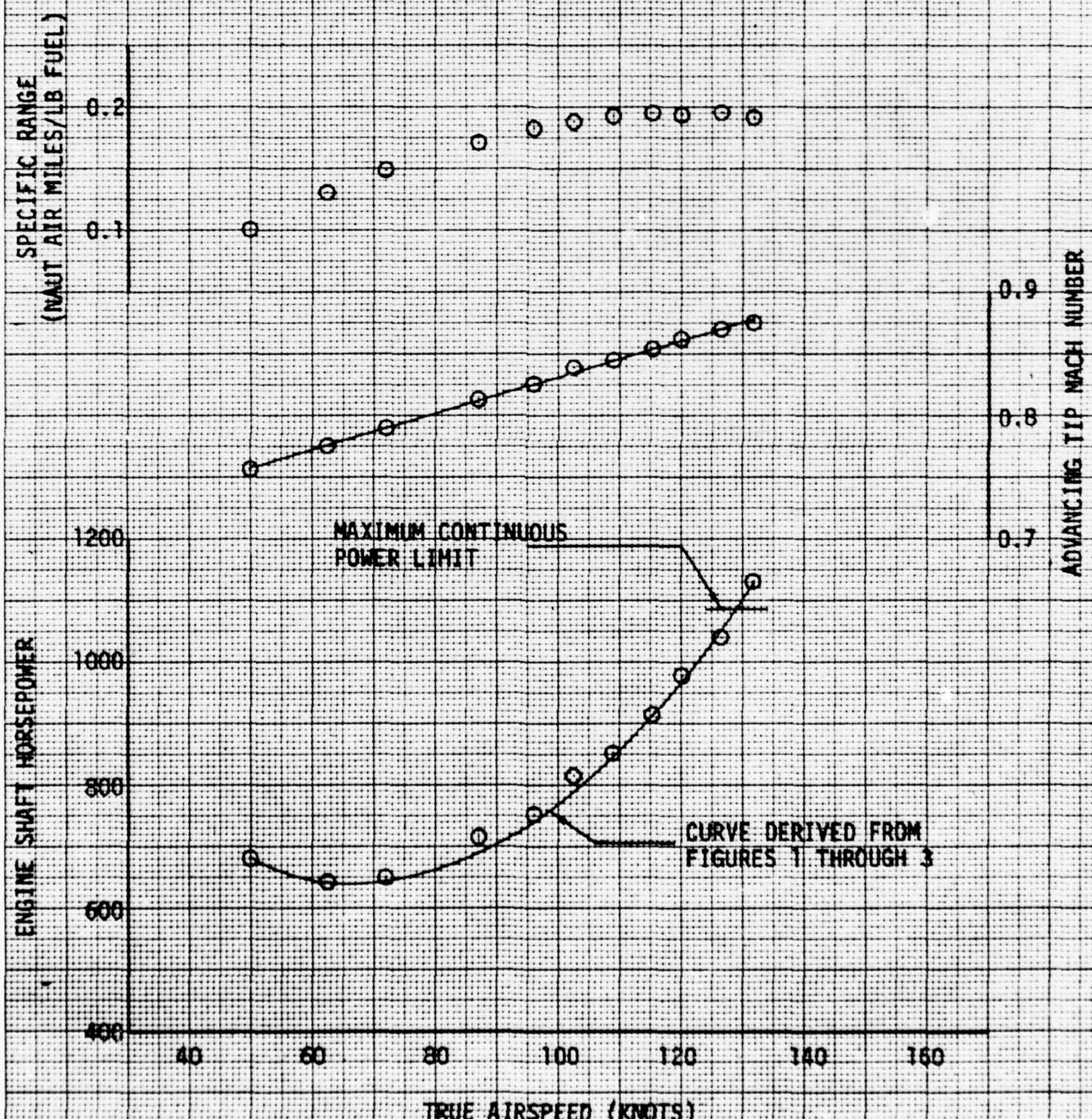


FIGURE 7
LEVEL FLIGHT PERFORMANCE
YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
9720	192.4(FWD)	0.2 RT	8320	8.5	324	0.006202	8-TOW

NOTES: 1. B-540 ROTOR INSTALLED
2. ZERO SIDESLIP TRIM CONDITION

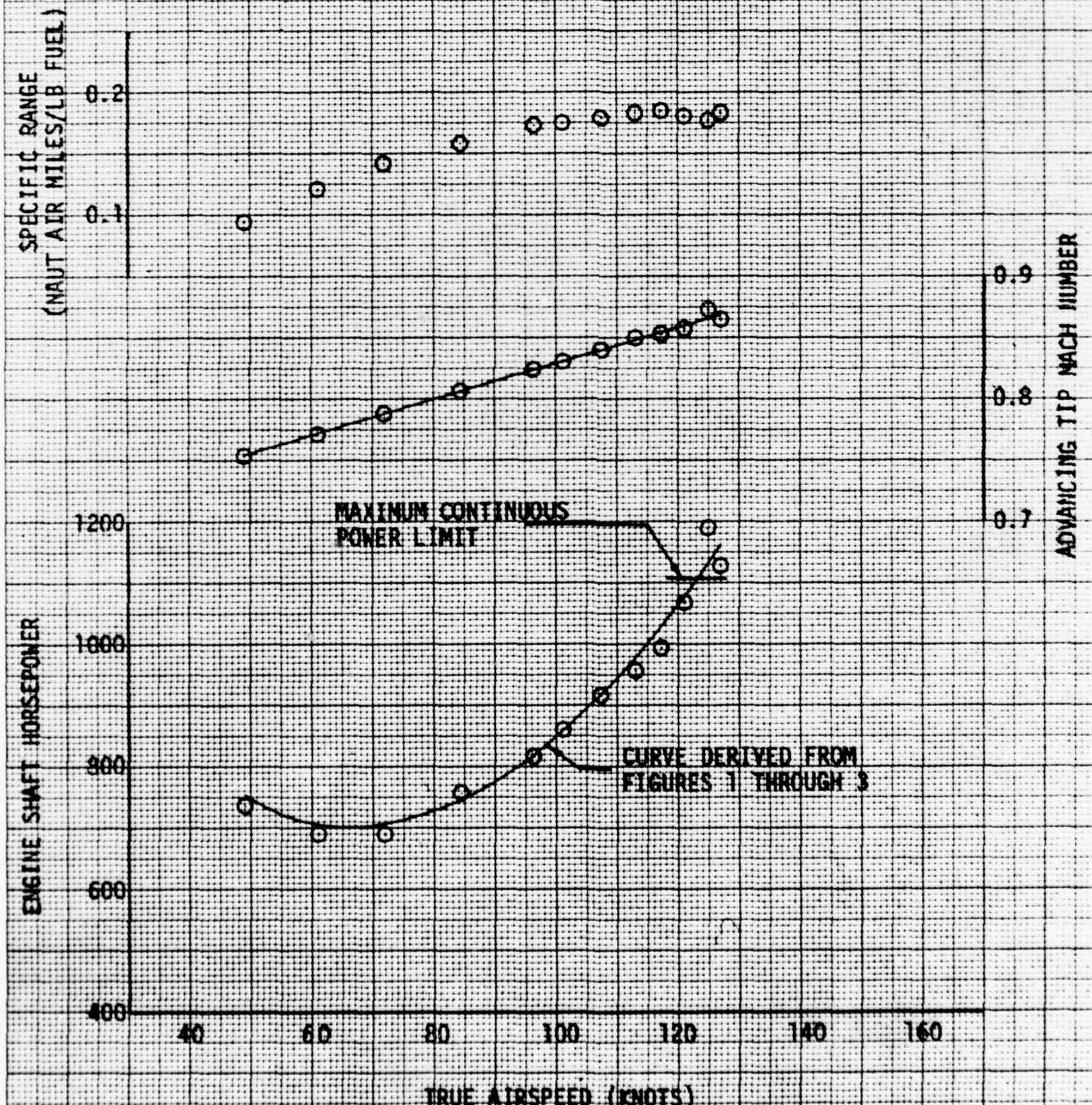


FIGURE 8
LEVEL FLIGHT PERFORMANCE
YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
9720	192.4(FWD)	0.2 RT	9700	5.5	324	0.006476	8-TOW

NOTES: 1. B-540 ROTOR INSTALLED
2. ZERO SIDESLIP TRIM CONDITION

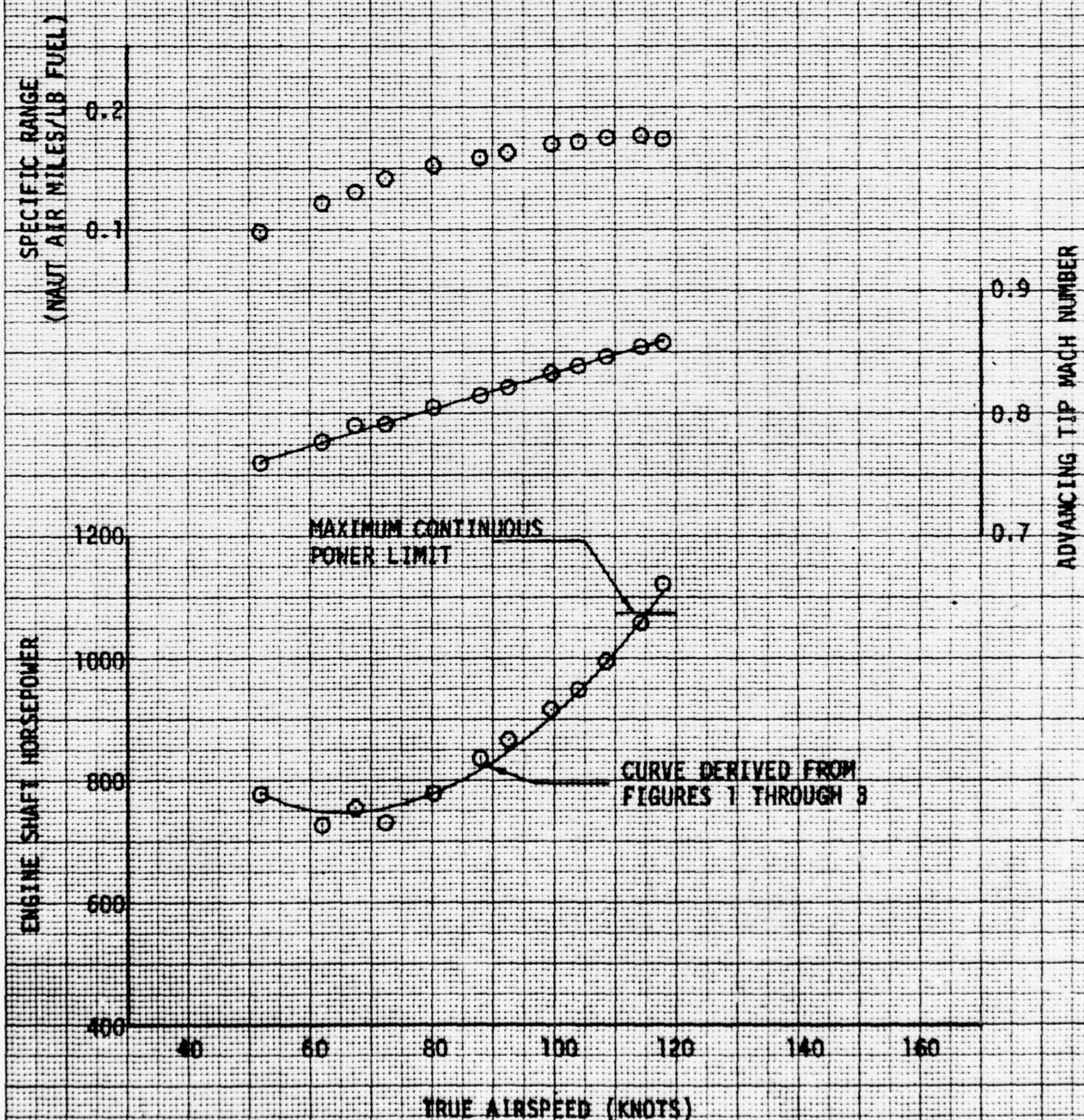


FIGURE 9

LEVEL FLIGHT PERFORMANCE

YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
9680	192.4(FWD)	0.2 RT	10900	5.0	324	0.006694	8-TOW

NOTES: 1. B-540 ROTOR INSTALLED
2. ZERO SIDESLIP TRIM CONDITION

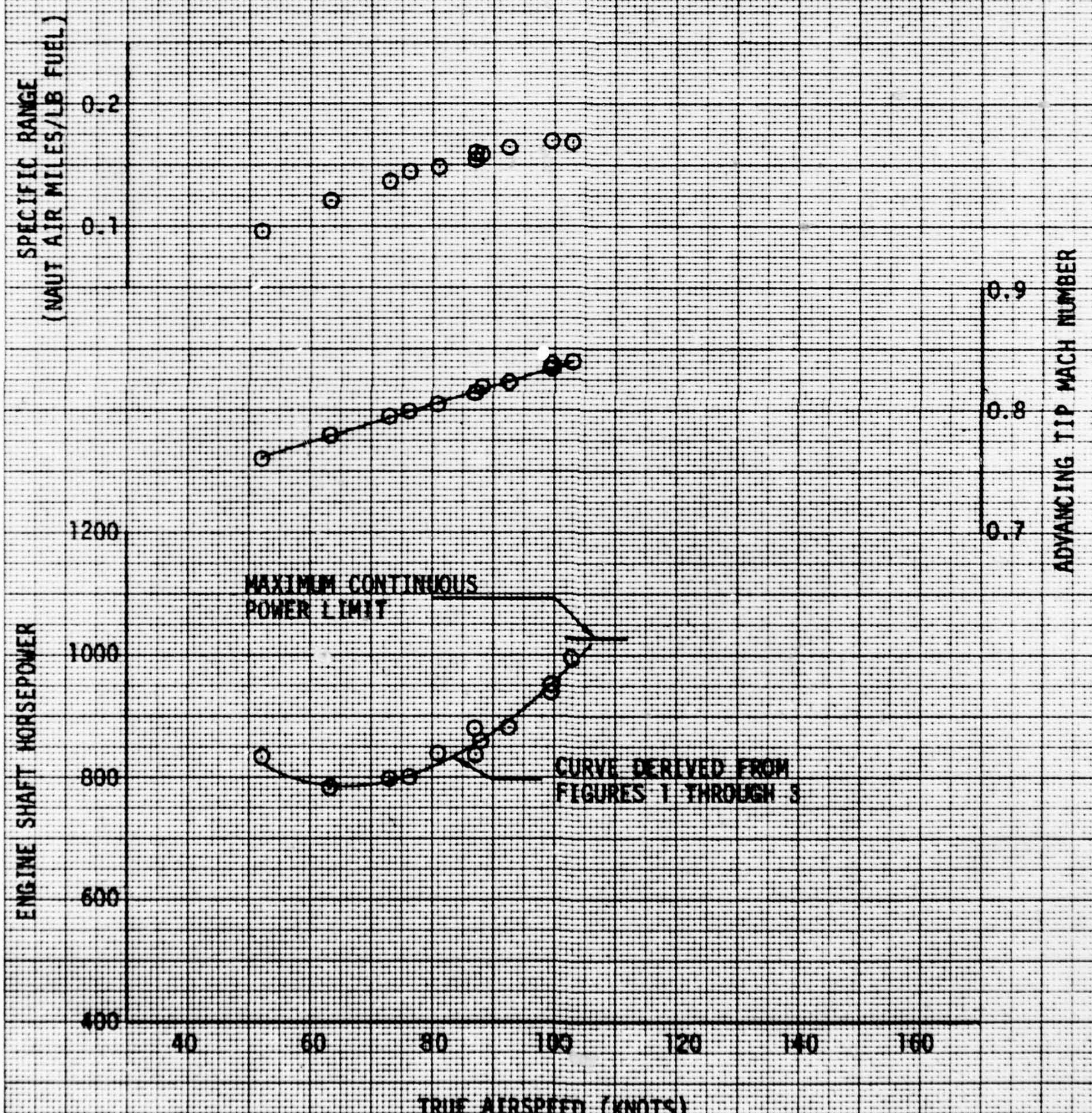


FIGURE 10
LEVEL FLIGHT PERFORMANCE
YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
8320	192.6(FWD)	0.2 RT	6400	13.0	324	0.005003	CLEAN

NOTES: 1. B-540 ROTOR INSTALLED
2. ZERO SIDESLIP TRIM CONDITION

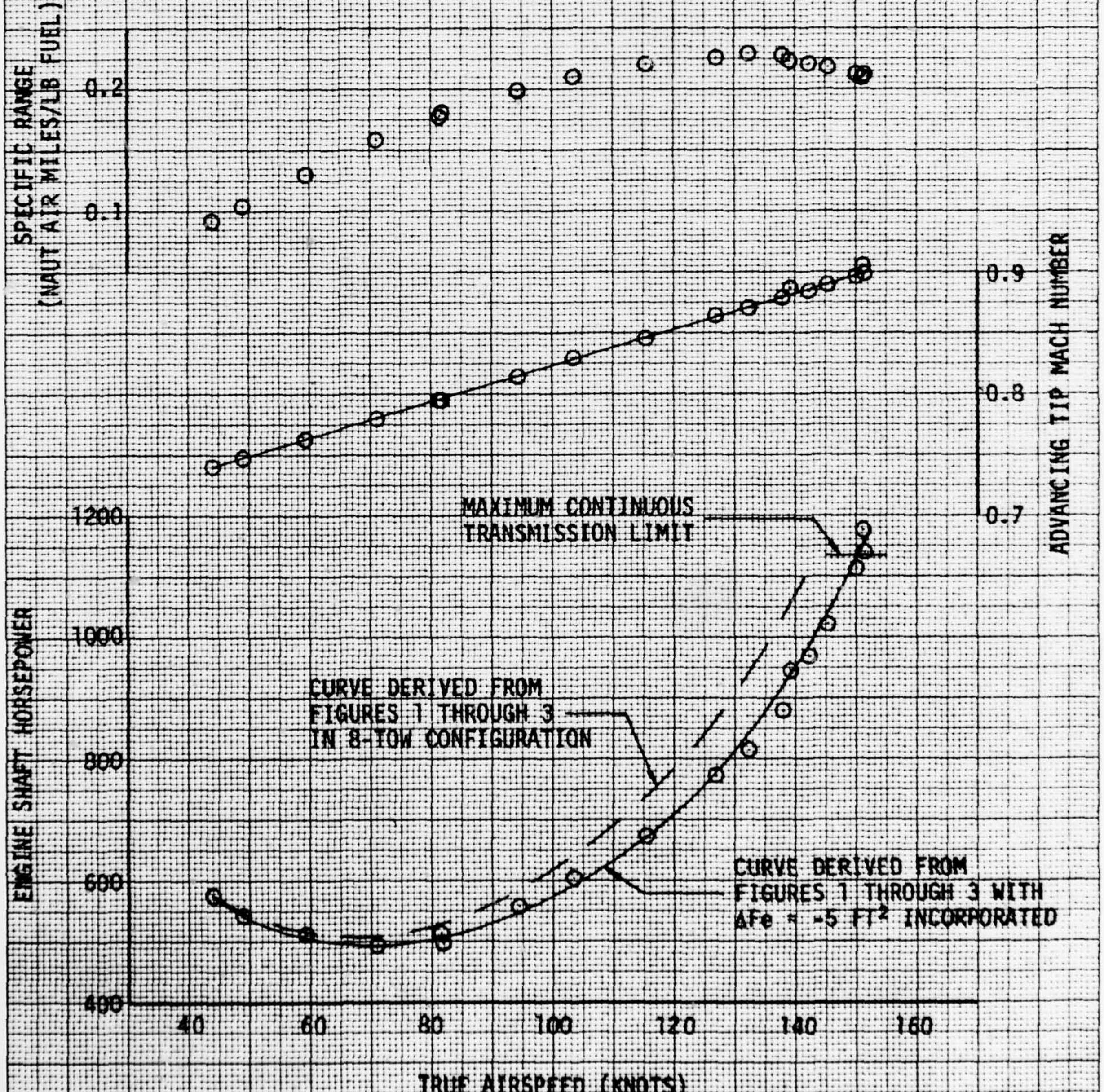


FIGURE 11
LEVEL FLIGHT PERFORMANCE
YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
9140	192.6(FWD)	0.2 RT	9280	5.5	324	0.006010	CLEAN

NOTES: 1. B-540 ROTOR INSTALLED
2. ZERO SIDESLIP TRIM CONDITION

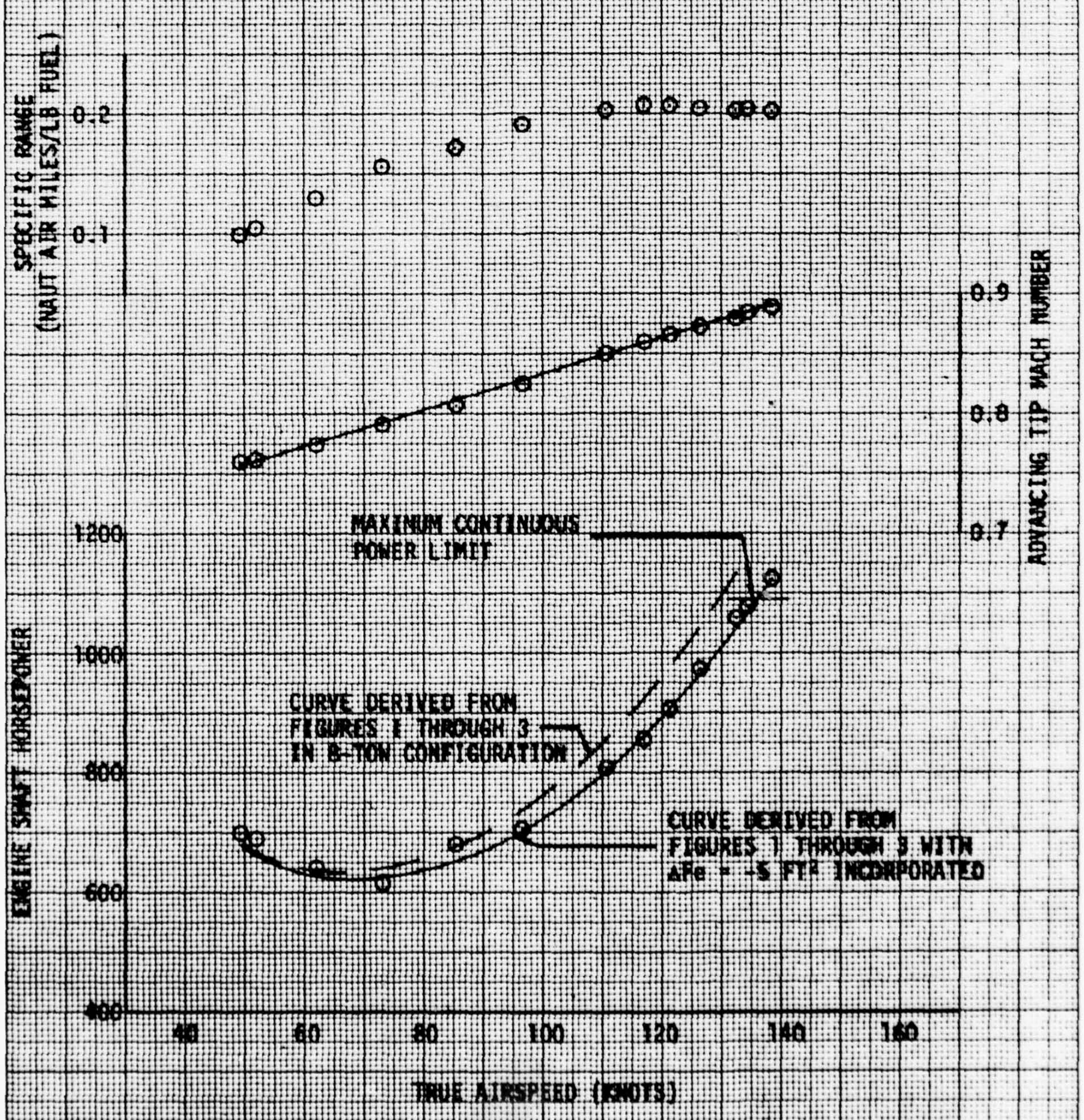
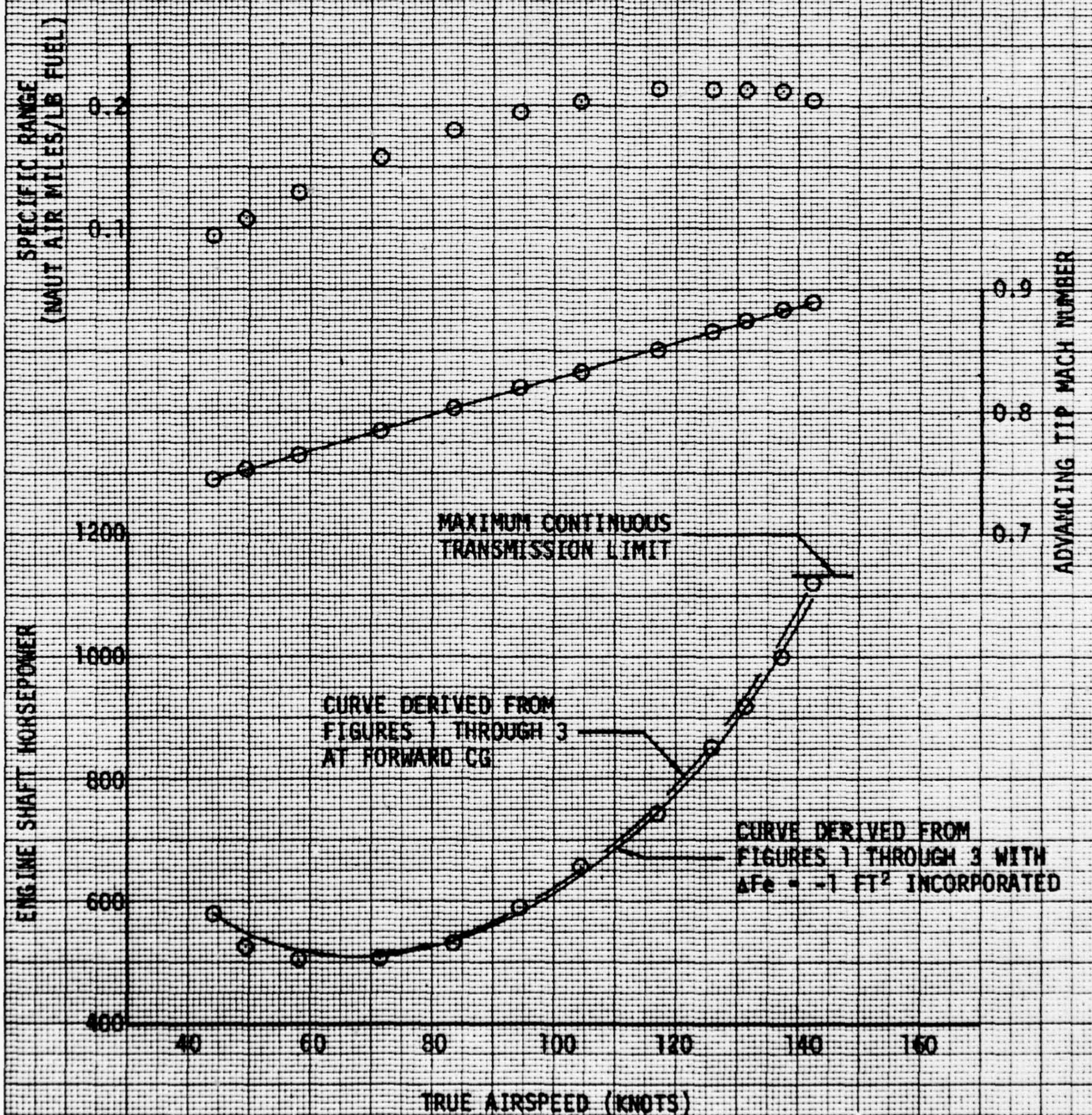


FIGURE 12
LEVEL FLIGHT PERFORMANCE
YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
8380	199.5(AFT)	0.2 RT	6220	10.0	324	0.005011	8-TOW

NOTES: 1. B-540 ROTOR INSTALLED
2. ZERO SIDESLIP TRIM CONDITION



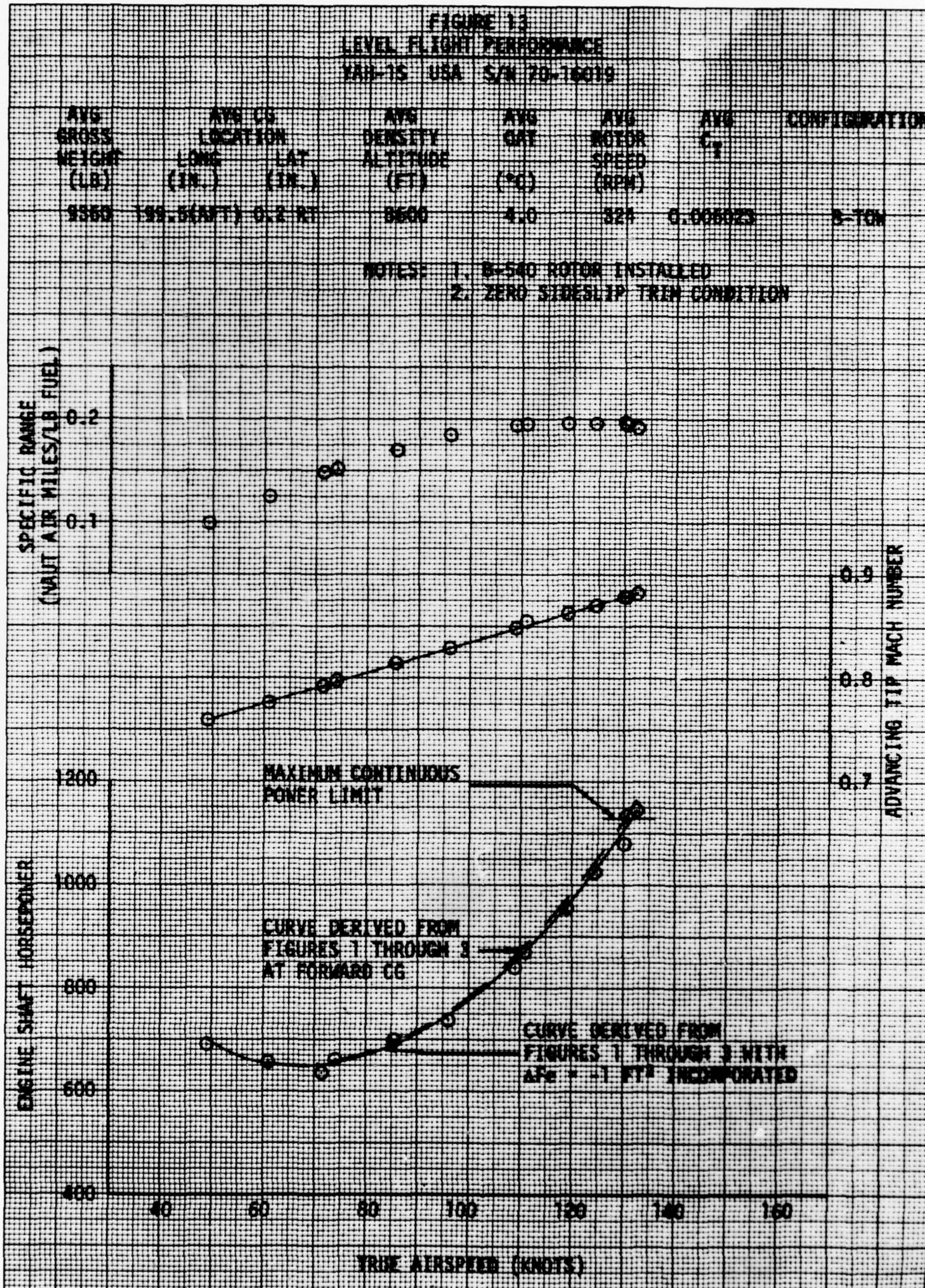


FIGURE 13
LEVEL FLIGHT PERFORMANCE
YAH-1S USA S/N 70-16019
AVG GROSS WEIGHT (LB)
AVG CG LOCATION LONG (IN.) LAT (IN.)
AVG DENSITY ALTITUDE (FT)
AVG OAT (°C)
AVG ROTOR SPEED (RPM)
AVG C_T
CONFIGURATION
9360 195.5(AFT) 0.2 RT 8600 4.0 324 0.006023 B-TOW
NOTES: 1. B-540 ROTOR INSTALLED
2. ZERO SIDESLIP TRIM CONDITION
SPECIFIC RANGE (NAUT AIR MILES/LB FUEL)
0.2
0.1
ADVANCING TIP MACH NUMBER
0.9
0.8
0.7
MAXIMUM CONTINUOUS POWER LIMIT
CURVE DERIVED FROM FIGURES 1 THROUGH 3 AT FORWARD CG
CURVE DERIVED FROM FIGURES 1 THROUGH 3 WITH ΔFe = -1 FT² INCORPORATED
ENGINE SHAFT HORSEPOWER
1200
1000
800
600
400
40
60
80
100
120
140
160
TRUE AIRSPEED (KNOTS)

FIGURE 14
AUTOROTATIONAL DESCENT PERFORMANCE
YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	AVG C_T	CONFIGURATION
9760	192.5(FWD)	0.2 RT	5000	11.0	324	0.005625	8-TOW

NOTES: 1. B-540 ROTOR INSTALLED
2. ZERO SIDESLIP TRIM CONDITION

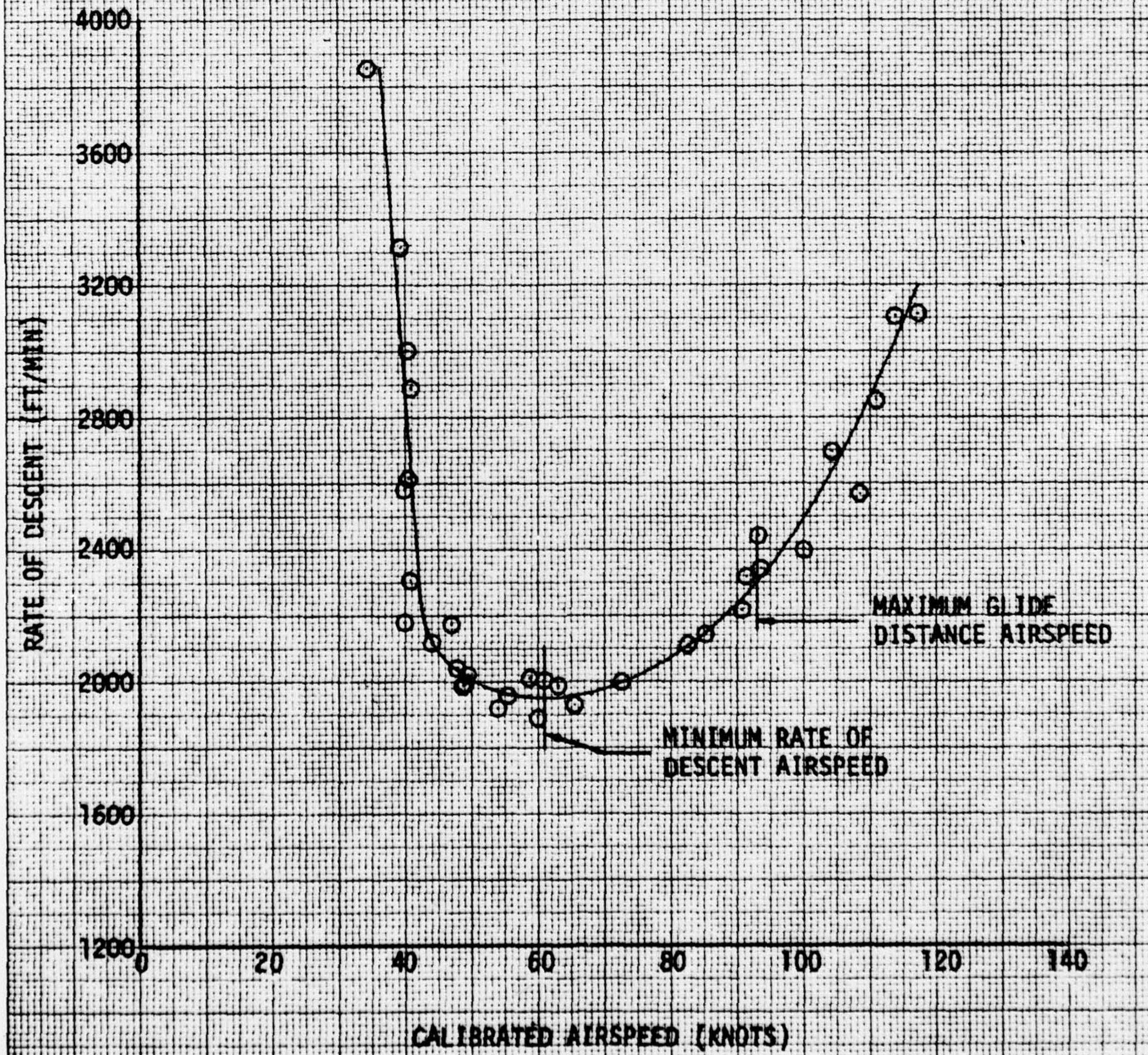


FIGURE 15
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
YAH-15 USA S/N 70-16019

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	CONFIGURATION
○	9180	192.6(FWD)	0.2 RT	9240	6.5	324	LEVEL	8-TOW
□	9140	192.6(FWD)	0.2 RT	9280	5.5	324	LEVEL	CLEAN
◇	9360	199.5(AFT)	0.2 RT	8600	4.0	324	LEVEL	8-TOW

NOTES: 1. B-540 ROTOR INSTALLED
2. ZERO SIDESLIP TRIM CONDITION

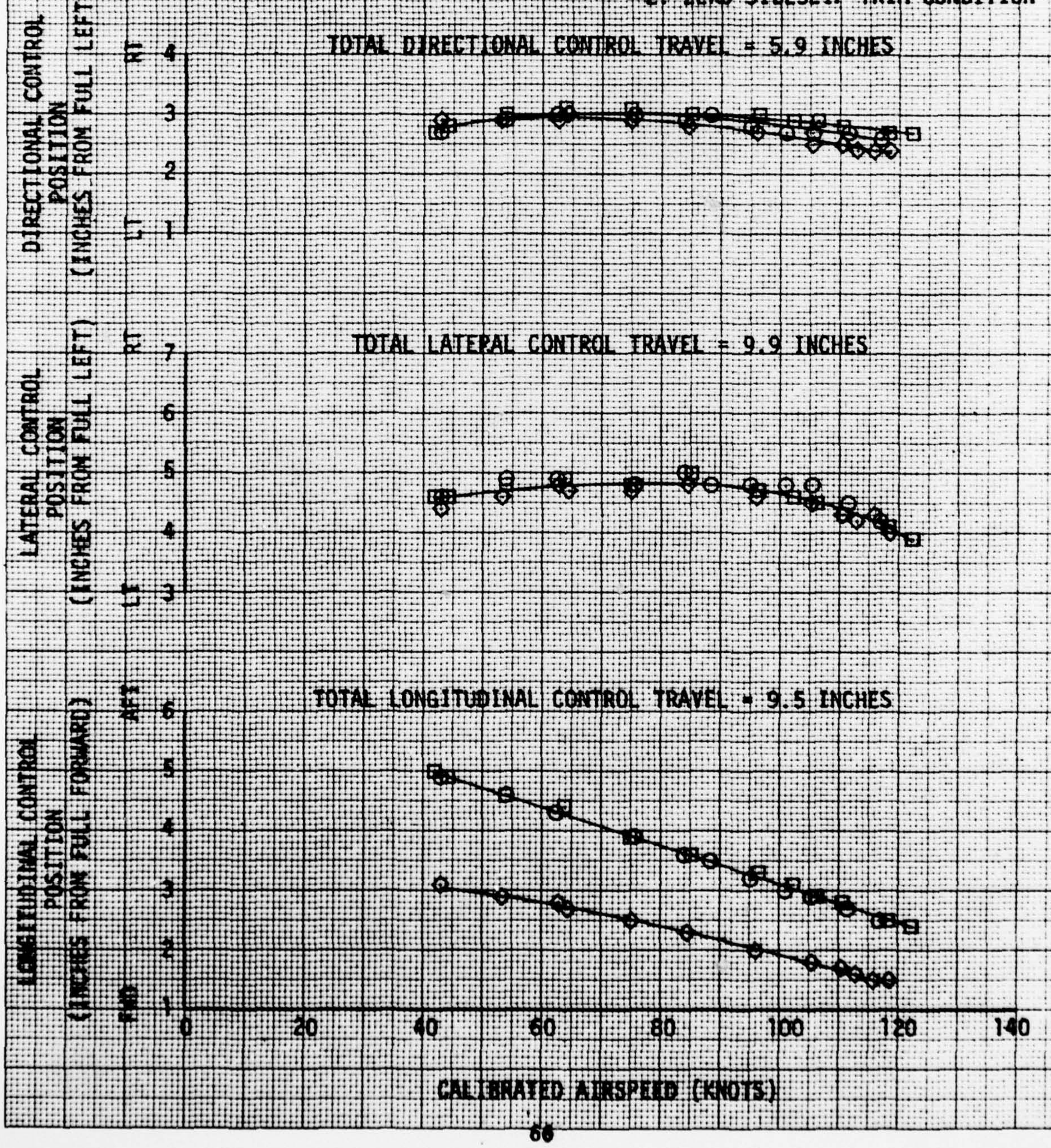


FIGURE 16
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
YAH-1S USA S/N 70-16019

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	CONFIGURATION
○	9360	192.7(FWD)	0.2 RT	5020	10.5	324	MCP CLIMB	B-TOW
□	9320	192.7(FWD)	0.2 RT	5000	10.5	324	AUTOROTATION	B-TOW

NOTES: 1. B-540 ROTOR INSTALLED
2. ZERO SIDESLIP TRIM CONDITION

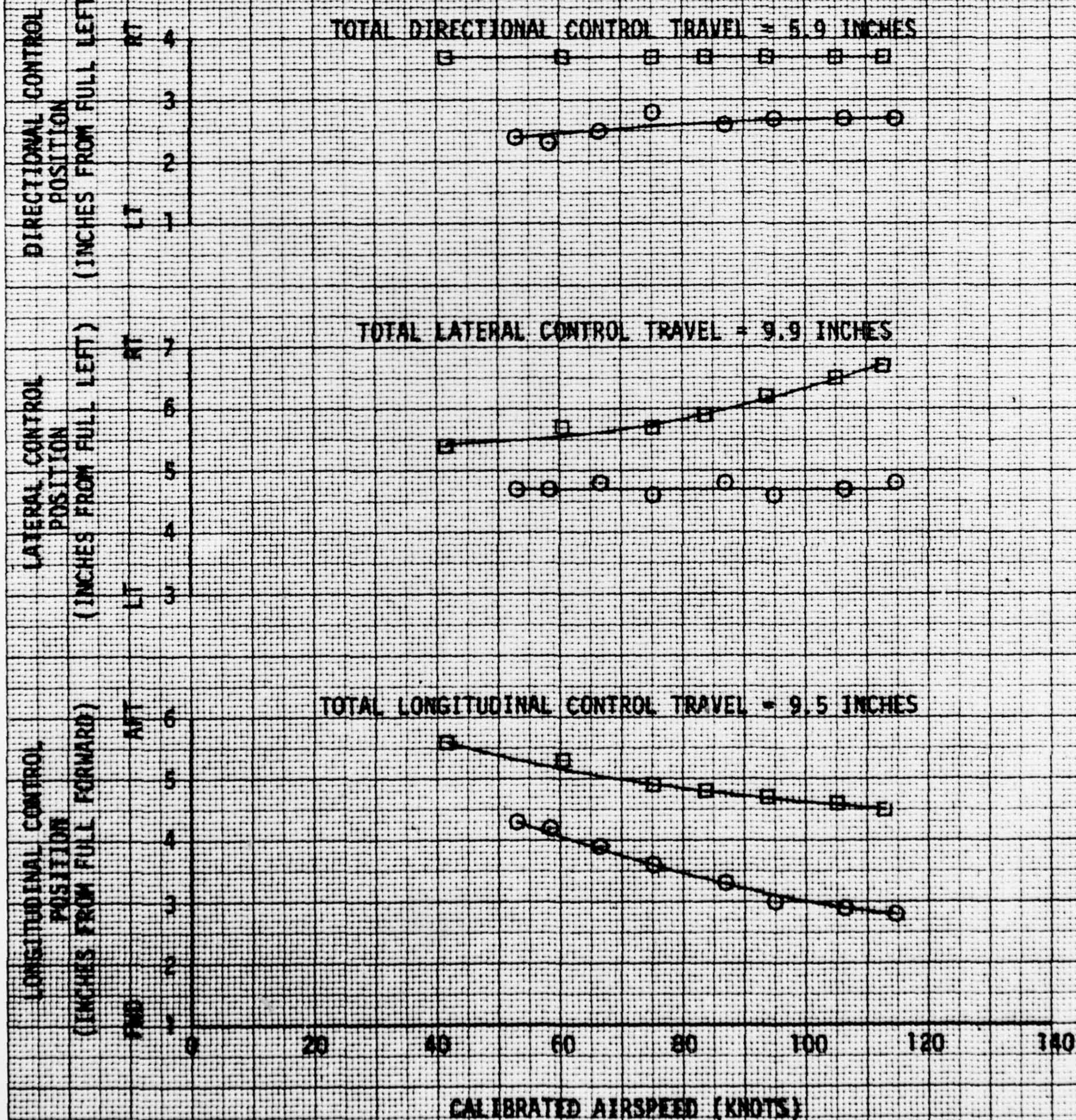


FIGURE 17

COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY

YAH-1S USA S/N 70-16019

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIGURATION
○	9240	199.7(AFT)	0.2 RT	5020	17.5	324	8-TOW
□	9580	199.8(AFT)	0.2 RT	4840	17.0	324	8-TOW

NOTES: 1. SHADED SYMBOLS DENOTE LEVEL FLIGHT TRIM POINT.
2. K-747 ROTOR INSTALLED.
3. BALL-CENTERED TRIM CONDITION.

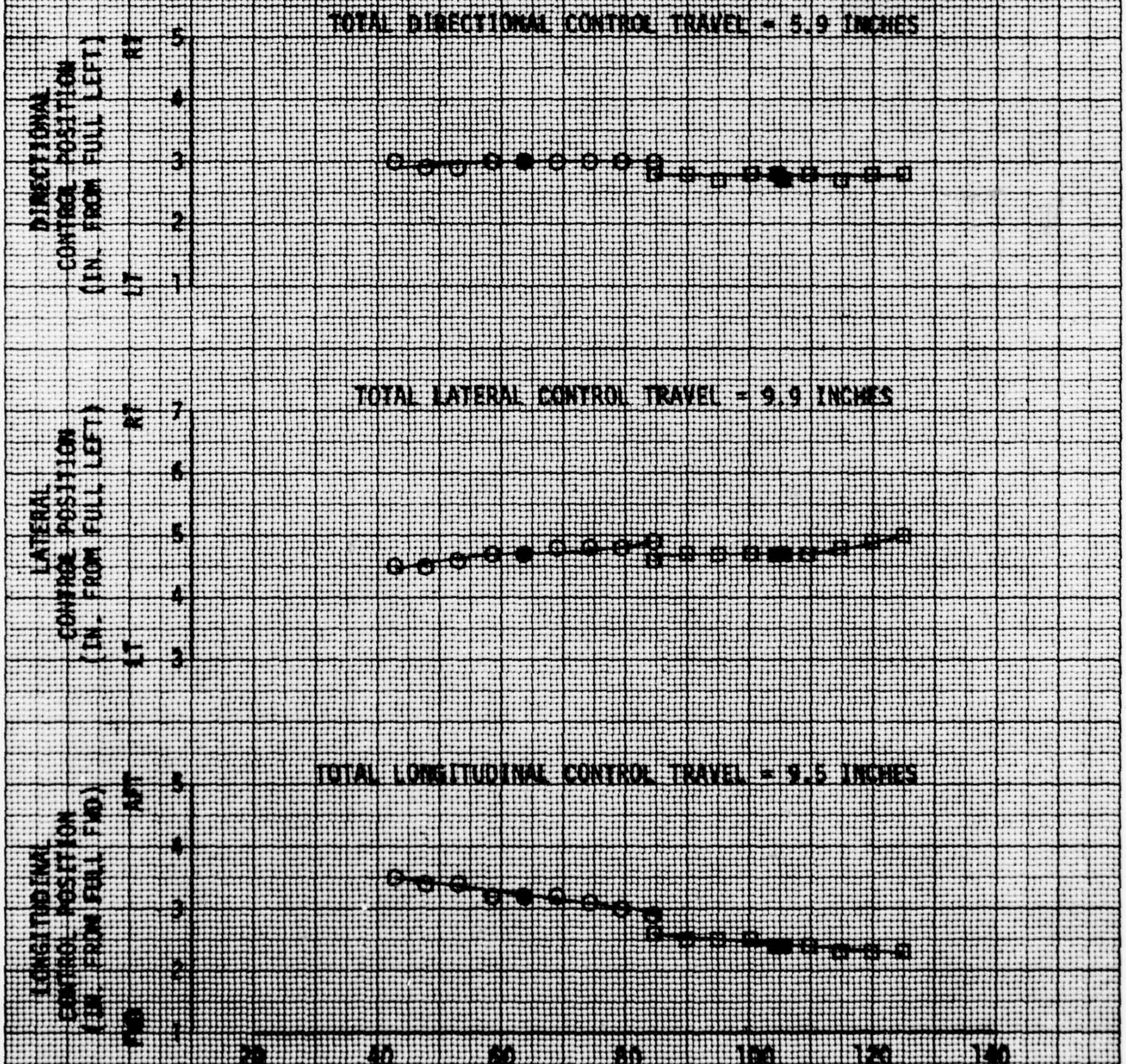


FIGURE 18
STATIC LATERAL-DIRECTIONAL STABILITY
YAH-1S USA S/N 70-16019

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	CONFIGURATION
○	9120	199.7(AFT)	0.2 RT	5200	18.0	324	64	8-TOW
□	7800	199.4(AFT)	0.2 RT	4960	13.0	324	61	CLEAN

NOTES:
1. COLLECTIVE CONTROL POSITION HELD FIXED DURING TEST.
2. SHADED SYMBOLS DENOTE LEVEL FLIGHT TRIM POINT.
3. K-747 ROTOR INSTALLED.

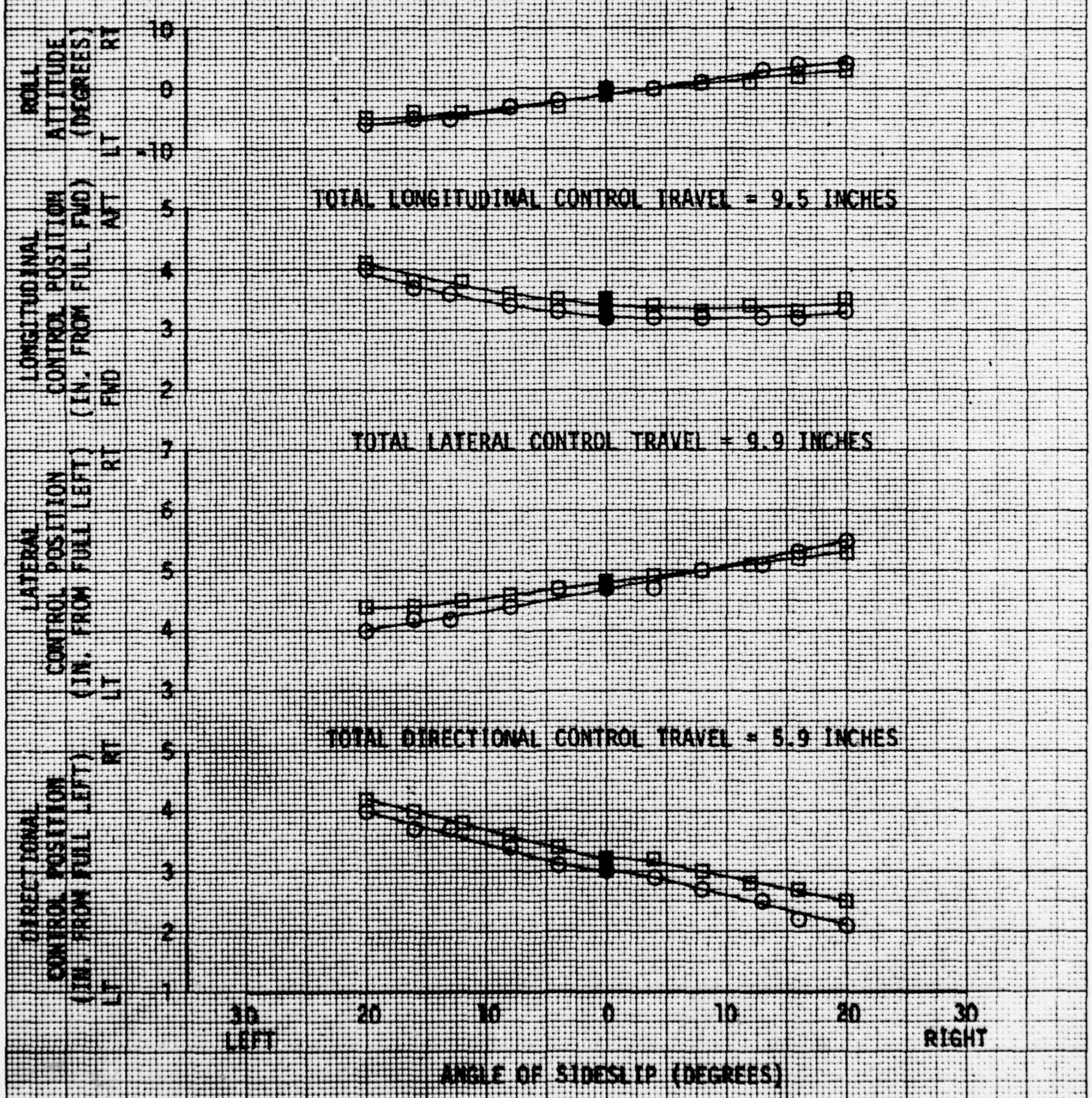


FIGURE 19
STATIC LATERAL-DIRECTIONAL STABILITY
YAH-1S USA S/N 70-16019

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	CONFIGURATION
⊙	9440	199.8(AFT)	0.2 RT	4980	18.0	324	105	8-TOW
⊡	8040	199.5(AFT)	0.2 RT	4820	13.5	324	102	CLEAN

NOTES: 1. COLLECTIVE CONTROL POSITION HELD FIXED DURING TEST.
2. SHADED SYMBOLS DENOTE LEVEL FLIGHT TRIM POINT.
3. K-747 ROTOR INSTALLED.

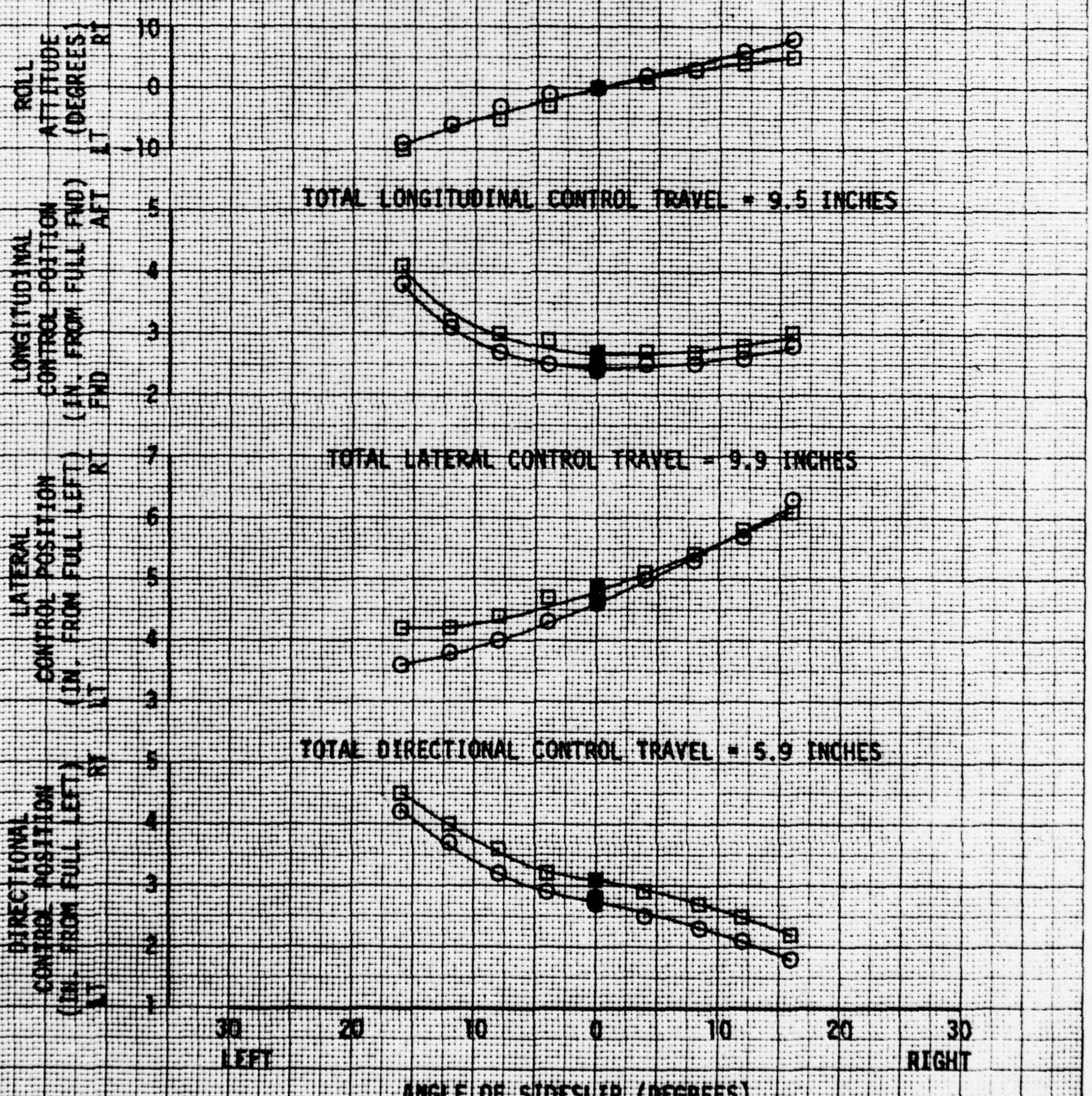


FIGURE 20
MANEUVERING STABILITY
YAH-1S USA S/N 70-16019

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	CONFIGURATION
○	9640	196.0(MID)	0.2 RT	7160	17.0	324	LT TURN	8-TOW
□	9520	195.9(MID)	0.2 RT	7100	17.0	324	RT TURN	8-TOW
◇	9460	195.8(MID)	0.2 RT	7100	17.0	324	PULL UP, PUSH OVER	8-TOW

NOTES:
1. SHADED SYMBOLS DENOTE TRIM POINT AT 1225 SHP.
2. SCAS ON.
3. K-747 ROTOR INSTALLED.
4. ZERO SIDESLIP TRIM CONDITION

TRIM CALIBRATED AIRSPEED = 64 KNOTS

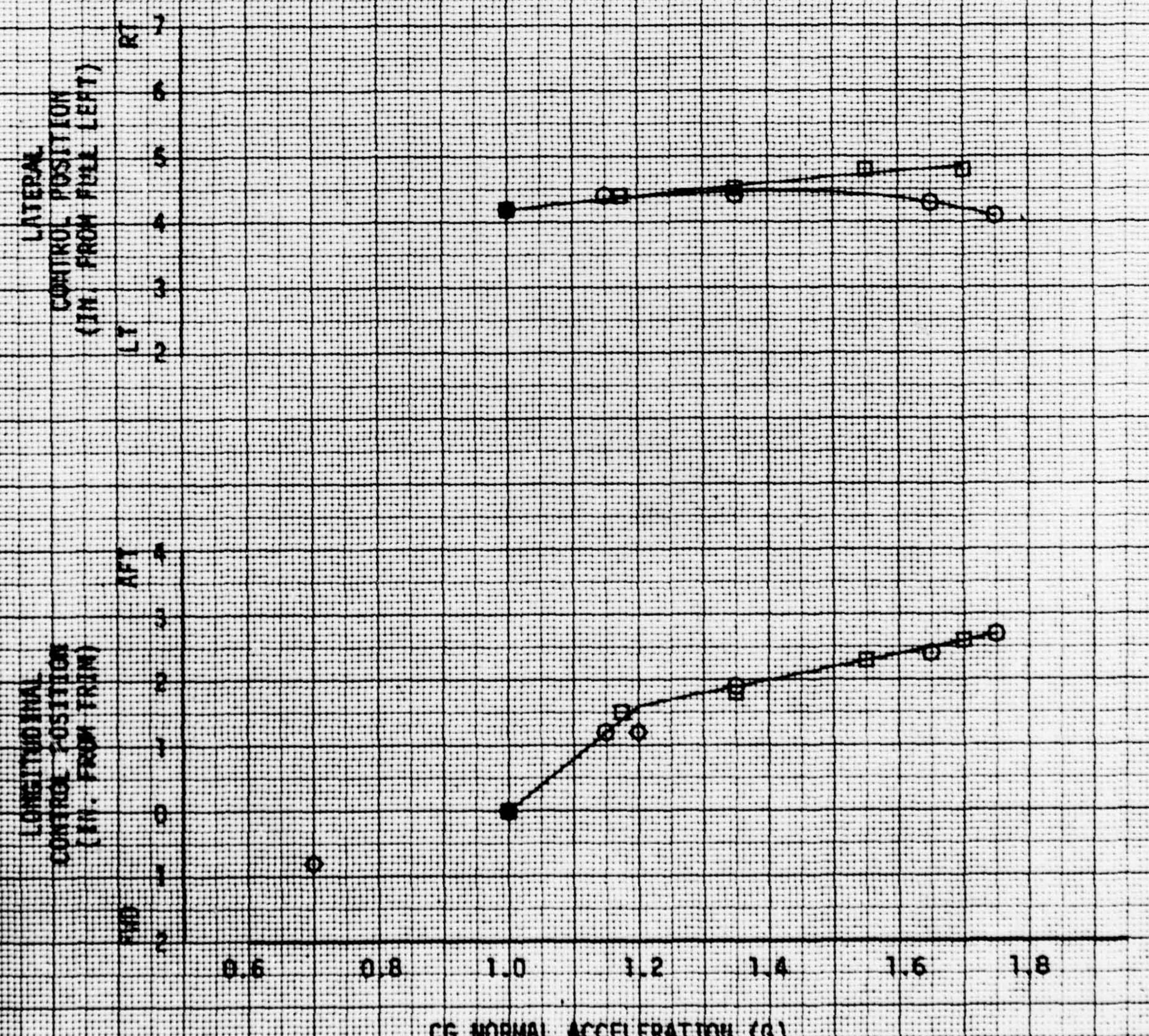


FIGURE 21
MANEUVERING STABILITY
YAH-1S USA S/N 70-16019

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM FLIGHT CONDITION	CONFIGURATION
○	10040	196.3(MID)	0.2 RT	6620	18.0	324	LT TURN	8-TOW
□	9840	196.1(MID)	0.2 RT	6600	18.0	324	RT TURN	8-TOW
◇	9760	196.1(MID)	0.2 RT	6600	18.0	324	PULL UP, PUSH OVER	8-TOW

NOTES:
1. SHADED SYMBOLS DENOTE TRIM POINT AT 1145 SHP.
2. SCAS ON.
3. K-747 ROTOR INSTALLED.
4. ZERO SIDESLIP TRIM CONDITION.

TRIM CALIBRATED AIRSPEED = 105 KNOTS

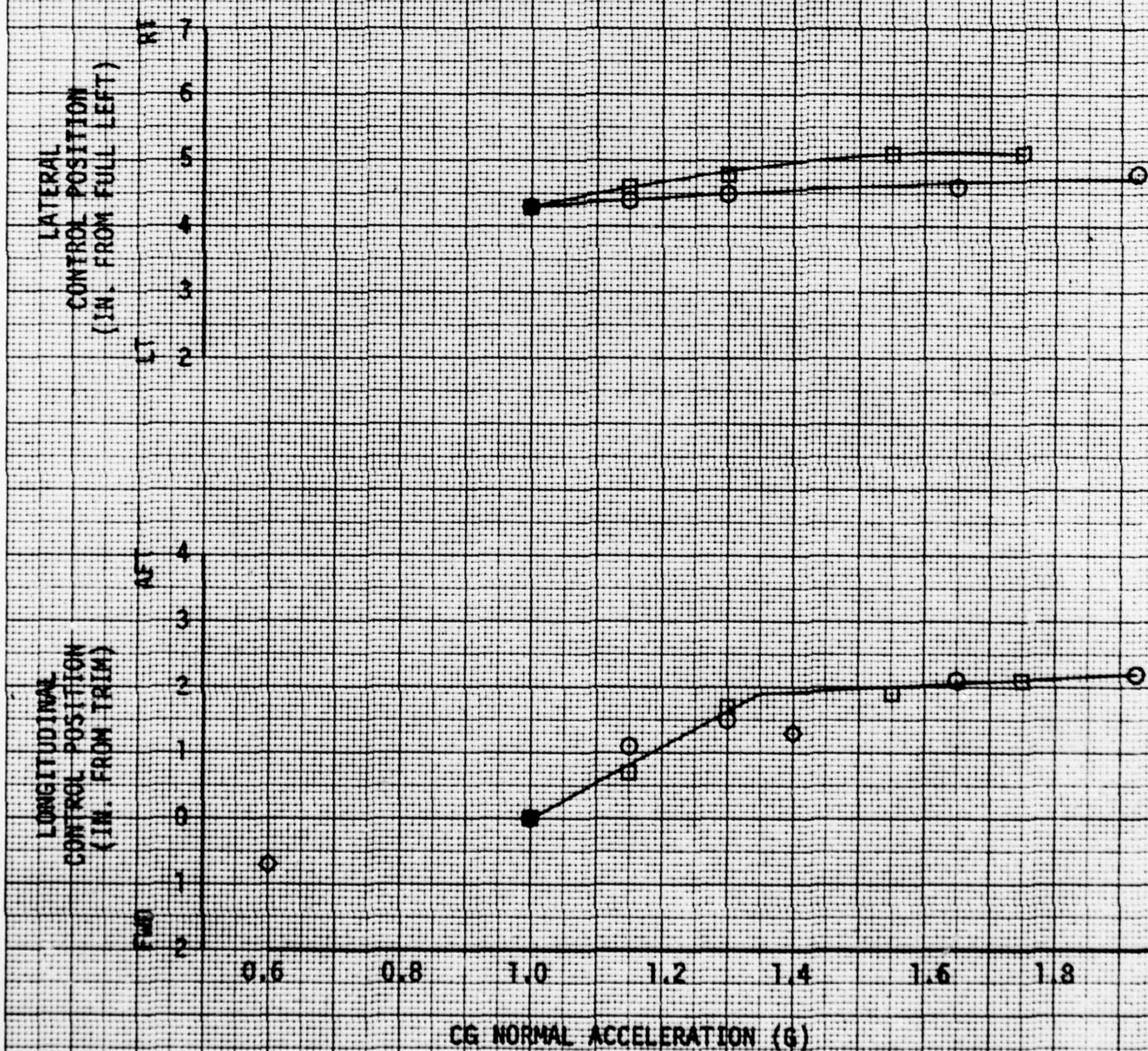


FIGURE 22
K-747 ROTOR TO PYLON FAIRING INTERFERENCE
YAH-1S USA S/N 70-16019

NOTES:
1. SHADED AREA REPRESENTS K-747 ROTOR AND UPPER PYLON FAIRING CONTACT.
2. MAXIMUM FLAPPING ANGLE = 12.25°
3. NO BLADE BENDING
4. BLADE AZIMUTH APPROXIMATELY 15° ADVANCED FROM AIRCRAFT CENTERLINE
5. DIRECTIONAL CONTROL CENTERED
6. CONTROL PATTERN DETERMINED WITH COLLECTIVE CONTROL FULL DOWN
7. TOTAL CONTROL DISPLACEMENT:
   LONGITUDINAL = 9.5 INCHES
   LATERAL - 9.9 INCHES
   COLLECTIVE - 9.0 INCHES
8. ● - COLLECTIVE CONTROL POSITION - 9.0 INCHES
   ▲ - COLLECTIVE CONTROL POSITION = 8.1 INCHES
   ■ - COLLECTIVE CONTROL POSITION = 7.2 INCHES
   ◆ - COLLECTIVE CONTROL POSITION = 6.3 INCHES

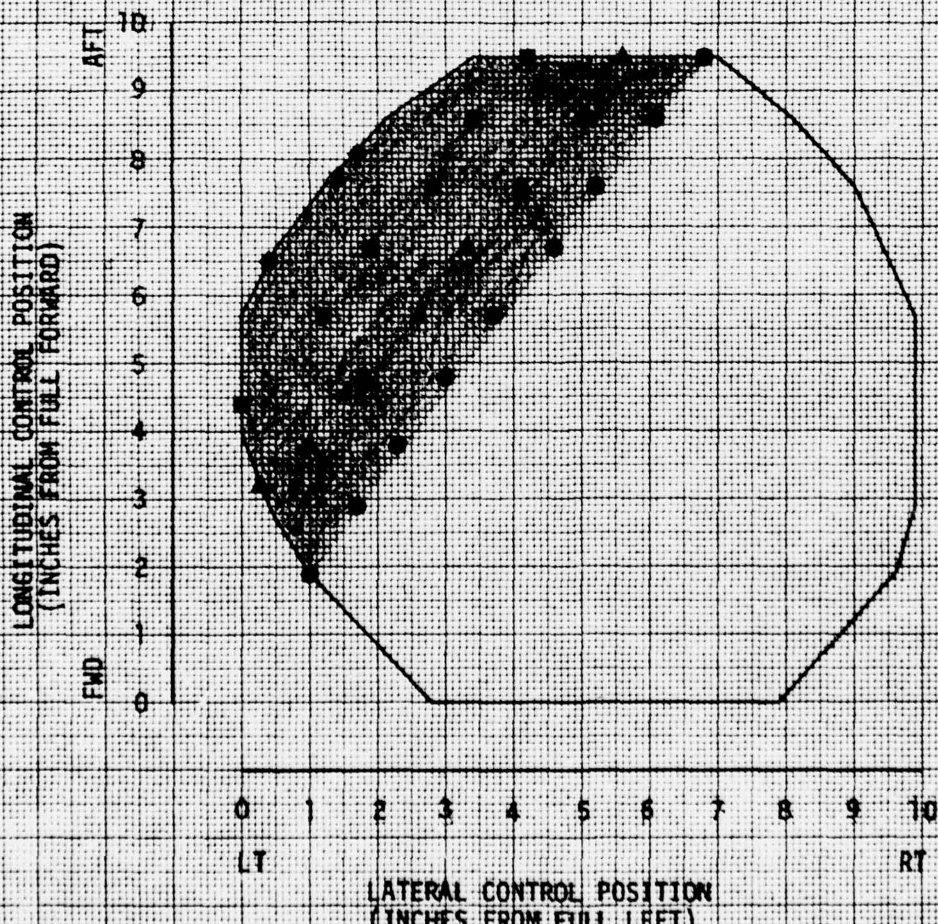


FIGURE 25
AIRSPEED CALIBRATION SHIP SYSTEM
YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN)	AVG CG LOCATION LAT (IN)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIGURATION
8320	199.8(AFT)	.2 RT	5220	11.5	324	CLEAN

NOTES:
1. DATA OBTAINED IN LEVEL FLIGHT
2. PACE METHOD UTILIZED
3. K-747 ROTOR INSTALLED
4. BALL-CENTERED TRIM CONDITION

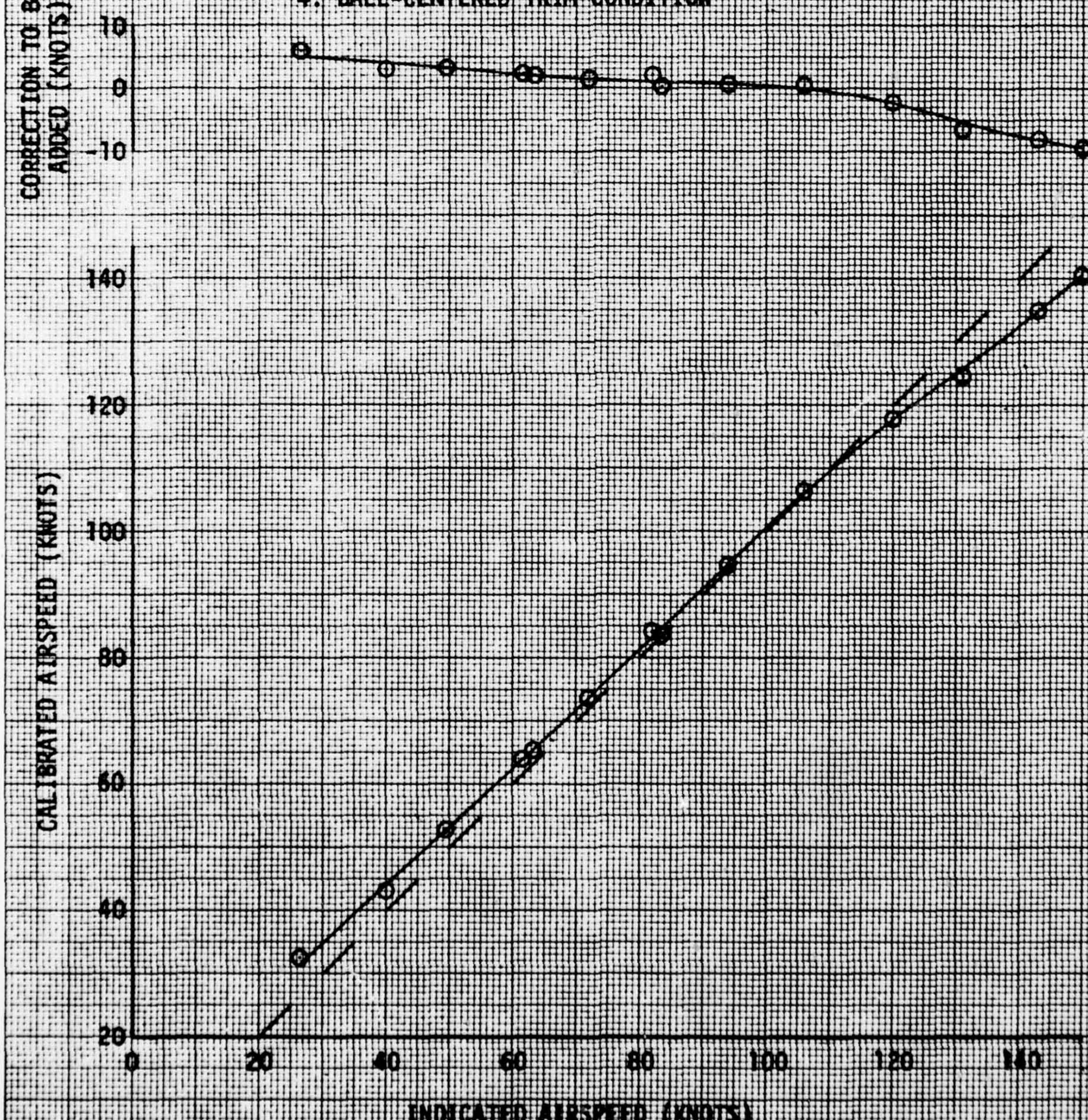
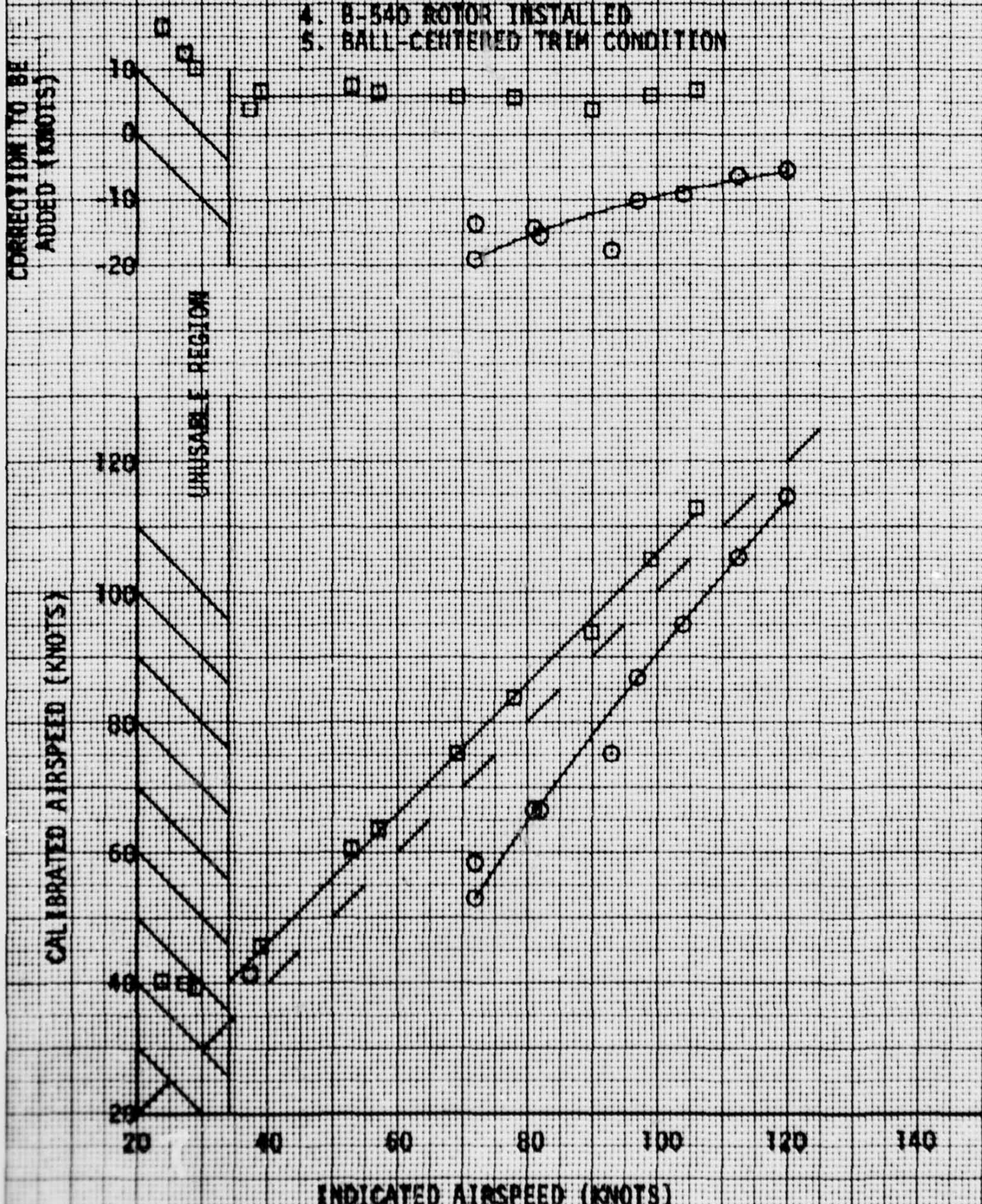


FIGURE 24
AIRSPEED CALIBRATION SHIP SYSTEM
YAH-1S USA S/N 70-16019

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (IN.)	AVG CG LOCATION LAT (IN.)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIGURATION
9340	192.7(FWD)	.2 RT	5020	10.5	324	8-TOW

NOTES: 1. ○ DATA OBTAINED IN CLIMBING FLIGHT
2. □ DATA OBTAINED IN AUTOROTATIONAL FLIGHT
3. TRAILING BOMB METHOD UTILIZED
4. B-540 ROTOR INSTALLED
5. BALL-CENTERED TRIM CONDITION



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